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PROBLEM OF THE MONTICULIPOROIDEA. I.

THE Monticuliporoidea, comprising the greater part of the so-called Paleozoic Bryozoa, are a comparatively neglected group of fossils, as evidenced in such ways as frequent omission or slight mention of them in lists of fossils or descriptions of faunas. They are not, however, really without great scientific value, but rather their unpopularity may be due to the fact that at present there is a real difficulty for the amateur, the collector, or the geologist in making use of them; this difficulty being magnified, moreover, by a too readily accepted supposition that these fossils are for none but gifted specialists to study. In fact, the specimens themselves are very often excellent, the species quite easy to learn or to identify, and well worthy of consideration as to scientific value in geologic faunas, and the entire group is of peculiar interest to biology.

Aside from the retarding supposition that the Monticuliporoidea are difficult, the present difficulties attending them are these: (1) the interpretation of the animal that built the honeycomb-structured organic remains is still uncertain; (2) the monographs in which they are described want censorship; (3) study of the fossil involves technique more or less. These obstructions are, however, not absolute. It is the aim of this discussion to render them better understood, and hence less feared.

Regarding their interpretation, uncertainty exists to the extent that all Monticuliporoidea may be contested as not true Bryozoa, but Tabulata or Alcyonarian corals, belonging then to a different subkingdom of animals. This uncertainty may be illustrated as to its attendant difficulties by reference to Eastman's[1] *Text-book of Paleontology*, Vol. I, where *Prasopora*, *Neuropora*, and many other genera appear twice, first under Cœlenterata and second under Bryozoa; the first following the text of Zittel, the second the authority of the translator's collaborator, who has taken the liberty to make some revision.

The fact that one cannot assert positively that species of the genus *Prasopora* and other genera were Cœlenterates or were Bryozoons, is due to outward similarity of these two groups and obscurity in the fossils as to class characters. Yet structural details as to minor characters are well preserved, and hence the distinction of species and their grouping into genera is not impracticable here more than in many other groups, since species may be distinguished clearly in fossils as in living organisms without knowledge of phylogenic relation to other classes. Ulrich, who considers them all as Bryozoa, and Nicholson, who treated them as corals, ought nevertheless to present the same determinations as to species, genera, and families. Their failure to agree is not due to that cause. However, the former, in Eastman's translation of Zittel (*op. cit.*), presents as families of Bryozoa (viz., Calloporidæ, etc.) those which, following Nicholson (*vide op. cit.*, pp. 103–105), are given as genera Callopora, etc., of Cœlenterata. Understanding this discrepancy, the handbook is as useful respecting these as other groups, and the fossils are as easily used under its guidance. The student may choose his authority or follow a happy median course.

The lack of censorship in Eastman's *Paleontology*, just mentioned, may serve to argue further need of it in other places. S. A. Miller's catalogue[2] divides the Monticuliporoidea species

[1] Text-book of Paleontology, by KARL A. VON ZITTEL, translated by Charles R. Eastman, 1900.

[2] S. A. MILLER, North American Geology and Paleontology.

between Cœlenterata and Bryozoa. Of other chief works, especially those of Nicholson,[1] we may trust E. O. Ulrich to have criticised them fully. They are conservative and excellent, but inadequate for the study of American fossils without the magnificent recent monographs by E. O. Ulrich[2] to supplement them. The last named, together with the chapter on Bryozoa in Eastman's *Paleontology*, would have offered a complete solution to the student for the study of the fossils and the involved problem of their affinities, if it were not for much obscurity in his definitions. One is compelled to criticise and to interpret anew from the fossils when endeavoring to follow him. In this connection it should be said also that the severe criticism of E. O. Ulrich, by S. A. Miller, *op. cit.*, while touching his works on Paleozoic Bryozoa, does not appear to reach by censorship of the species this group as much or as well as other ones, for the reason, evidently, that his knowledge of them did not permit him. Therefore, while all species are listed as equally valid, some will be found, nevertheless, to have been made upon wholly insufficient evidence and require to be freely eliminated. The most species will again be far easier to identify than their descriptions would lead one to expect. It appears, in short, necessary to admit the value of some earlier criticism[3] of this author, and to expect to find similarities and differences described with acuteness, while fanciful values are frequently attached to them.

Regarding the handling of fossil Monticuliporoidea, one should collect all specimens and in the laboratory select the better preserved ones to begin with. These may be assorted and identified by means of external characters. A common hand lens will suffice to reveal whatever may be not clear to the naked eye. To be sure, the exhaustive study of the material requires the making and use of thin sections when practicable, for often only by that means can the also important internal

[1] H. A. NICHOLSON, On the Structure and Affinities of the Genus Monticulipora 1881.

[2] Geol. Surv. Ill., Rept., Vol. VIII, and Geol. Surv., Minn., Final Rept., Vol. III.

[3] ROMINGER, Amer. Geol., Vol. VI, pp. 103 and 120, 1890.

structure be discovered. The use of thin sections is, however, necessarily limited to special cases. These would be when a new species is in hand and all characters possible should be discovered; or, when a described species is illustrated and described chiefly as to its internal structure, which too frequently is the case; or, when the external characters have been obliterated. Having identified the species and referred it to a genus, etc., by use of all characters, further recognition of specimens of the same can and should, with rare exception, be made to depend on external characters alone. As in studying Brachiopoda, for example, one must know them by external characters, even though examination of internal structures is required to determine affinities of the species.

The advantage of learning to recognize the species, genera, etc., by external characters is in the saving of time, since thousands can be examined in that way, while sectioning limits the labor of one man to at most twenty specimens per day; knowledge of the range and variability of one and many species is made practicable; it serves to direct to best advantage the use of thin sectioning; recognition of species even in the field becomes thereby entirely practicable. Having learned to know a group of species, or the fauna of a locality or of a zone, the specimens may be identified thereafter without the use of sectioning, and the difficulty of technique may be obviated by the geologist.

Thin sections of fossils may be made by the same process as bone or rock sections are ground, which need not be described here. It requires less skill, however, since they should not be ground to absolute thinness. Some simple appliance for measuring the cell dimensions is also needed.

Pains may be saved by attention in collecting, since each bed or zone may have a large proportion of species peculiar to it, and by avoiding mixing fossils of different zones, labor of again assorting is saved.

TREPOSTOMATA

A few selected species may illustrate what is to be looked for in Monticuliporoidea. Beginning with Trepostomata one

then has to do with the most problematic as to affinities of the so-called Paleozoic Bryozoa, *i. e.*, those which most resemble corals, proceeding then to those often supposed to be true Bryozoa, the Cryptostomata. Eastman's manual, *op. cit.*, includes them in the arrangement given below, and in the Order Gymnolæmata, which comprises most Bryozoa and all known fossil ones. Of those five divisions, the last named, Chilostomata, are all undoubtedly Bryozoa, but are not known in the Paleozoic rocks. The first, Cyclostomata, are, with few possible exceptions, all true Bryozoa, but few of them are Paleozoic. The second, third, and fourth comprise the Monticuliporoidea.

1. Cyclostomata (8 families).
2. Families doubtfully referred to Cyclostomata (4 families).
3. Trepostomata (7 families).
4. Cryptostomata (8 families).
5. Chilostomata (13 families).

In that arrangement those of doubtful affinities are embraced between the true Bryozoa. A fairer presentation of the problem may be given thus:

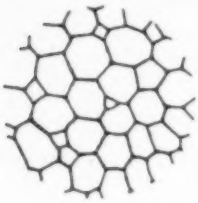
Tabulata (corals)——Trepostomata (?)——Cyclostomata (bryozoa)
| |
Cryptostomata (?) Chilostomata (bryozoa)

and it is in such association that the Monticuliporoidea should be studied. The group of "Doubtfully referred to Cyclostomata" are Trepostomata.

Beginning with one of the simpler Trepostomata,

Monotrypa magna Ulr. has a skeleton or zoarium one or two inches in diameter, composed of tubes or "cells" which radiate from an approximate center. It is nearly spherical if growing attached on one point, or discoid if on a flat surface, or, again, irregular. The center is the initial or oldest part, and from it one, or practically several, cells arise, and as these extend, others intercalate successively. A specimen divided radially (Pl. A, Fig. 2) shows parallel, approximately equal, cells, each tapering to a point at the inner end. The plan of growth is that of increase in number of cells proportionate to the increase in size of the zoarium. At the surface, the open cell ends are

JOUR. GEOL., Vol. IX, No. 1 Plate A



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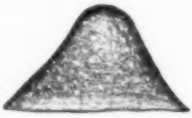

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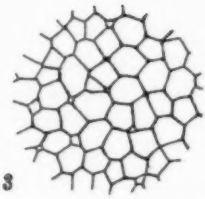

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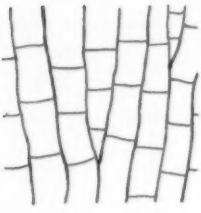

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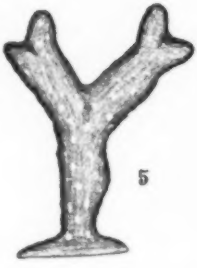

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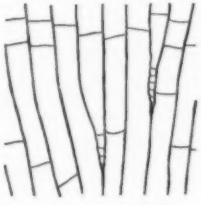

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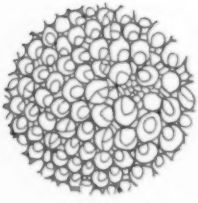

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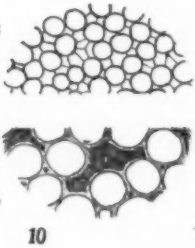

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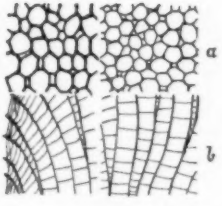

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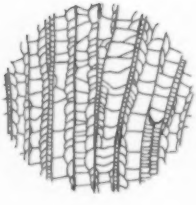

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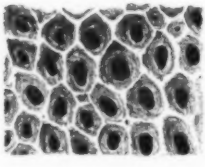

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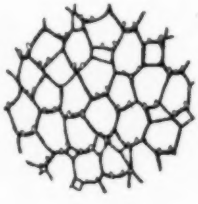

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approximately equal, and, like the cell throughout, are polygonal or hexagonal by reason of contact (Pl. A, Fig. 1). The incipient or expanding parts of cells are seen there as small tri-, or quadrangular openings at the angles between the older, larger cells. Crowding of the cells appears to prevent entire regularity in shape and size of each cell, and the walls are crenulate.

In speaking of cell one includes for each the half of the bounding wall, although the walls originally are dense, amalgamated, calcareous structures, not double further than that they were built not only by increment upon their margins, but also on the two surfaces. Theoretically there is a boundary plane or division between cells midway in the wall. They frequently split midway in the wall when fractured. The walls in this species are thin and show little or none of their growth structure. At a slight depth within each cell the last growth increment or layer crosses the cell opening and forms a transverse partition or false bottom, the so-called tabula. Tabulæ occur successively in all cells more or less regularly, but not corresponding in neighboring cells. They are a little more numerous in the incipient part of each cell. The wall edge of one cell cannot extend above those of its neighbors, from which it never separates.

The zoarium corresponds in structure to the following supposed manner of growth: It was covered when alive by numerous equal sized zooids which coalesced laterally, the lower part of each, however, extending into and secreting the walls forming the cell or zoœcium. Young zooids arose among them and, growing, extended relatively downward, building a new cell; the increase in number of zooids and, respectively, cells, being compensated by a necessary growth in radial length of cell wall to increase the surface of the inhabited zoarium. The tabulæ indicate successive planes where the bottom of the zooid rested between periods of necessitated self-extraction from the ever too long cell.

E. O. Ulrich assumes that the cells are "Zoœcia, directly superimposed upon one another so as to form long tubes

intersected by straight or curved partitions . . . ." That interpretation appears in form of a definition only; and not knowing how it could be applied to the initial part of cells, respectively young zooids, which then must be supposed to have required several generations to reach maturity, the other interpretation will be kept for the present, viz., that each cell is one zoœcium.

Variation in such species as this one would consist in the zoarium growing in one part more than another for some cause, being one-sided; or it is discoid because of perigene growth, *i. e.*, the cell increase is greatest around the margin; or, again, it is acrogene. The surface upon which it grew affected its growth also. The cells remain nearly uniformly large, the number of young cells seen at the surface varying. The cell walls appear uniformly thin.

Those characters are seen at the surface or in transverse thin section. Longitudinal section would show the tabulæ to vary, being fewest where cell length most rapidly increased, and the slightly differing rates of expansion of the cell initial. The atter character can also be estimated at the surface. Other species near to this one are in various ways more complex. Thus,

Diplotrypa limitaris Ulr. has nearly the same manner of growth as *Monotrypa magna*, differing in smaller size of cells and shapes of their apertures at the surface (Pl. A, Fig. 3). Here the number of immature cells nearly equals that of the mature ones. Longitudinal section shows that the young or initial part of each cell is long, slowly expanding, or even for some length not increasing, then quite quickly becoming full-sized, mature (see Fig. 4). The tabulæ are closer in these initial parts, technically called *mesopores*. The plan of growth thus differs from that of *Monotrypa magna* in that in the latter new cells appeared only as fast or numerous as they were to develop into mature cells. In *Diplotrypa* the new cells appear too rapidly, so to speak, and await their turn to expand into full size; hence the more

numerous small cells, mesopores, among the full-sized autocells at the surface. The calycal or open part of the cell is shallower in small cells or mesopores than in the larger ones, and that is true in all Monticuliporoidea. Also the autocells crowd the mesopores so that the former tend to become circular at the expense of the latter.

Callopora multitabulata Ulr. began like a *Mesotrypa*, but acrogene growth obtained (Pl. A, Fig. 5), the zoarium being long, cylindrical, branched, arising from a basal discoid expansion. The tips, or apices, are only then like small *Mesotrypa*. The greatest growth of zoarium and cell increase was at the zoarial ends, and there the cells increase centrally, so that some were being crowded away and turned their apertures to the peripheral surface, *i. e.*, away from the axis of growth (Pl. A, Fig. 6, *c*). The grown zoarium is thus composed of two regions, the axial or "immature" region of vertical cell part (Fig. 6, *b*, *a*), and the peripheral or "mature" of laterally directed cell (Fig. 6, *c*, *d*). In the peripheral region the cells grew slower in length, have thicker walls and more numerous tabulæ, and there are more mesopore cells. The apical parts also become finally slow-growing, thick-walled, with many tabulæ and many mesopores, and it is evident that the zoarium grew rapidly to nearly full size; then a retarded or "mature" growth followed. Renewed rapid zoarial growth and a second retardation stage often occurs, wherefore the terms immature and mature regions are presumptious terms. Peripheral and axial regions are better, since they leave the degree of maturity to be described. Upon the thick-walled peripheral and apical part there occur at nearly regular intervals elevations called monticules. These are occupied by a small group of larger-sized, cells with mesopores or young cells. On the thin-walled or growing apex, and hence in the axial region, these are represented by a group of likewise slightly large-sized cells, with abundant mesopores, resembling less distinct cell groups occurring in *Monotrypa*, etc. Nicholson proved monticules to be points of greater cell increase, and while

young cells may appear at any cell angle, their increase is greatest in the monticules or cell groups. In renewed rapid growth the peripheral monticules tend to develop into branches of the zoarium, but of course all could not. Thus monticules are similar to zoarial branches, but are not branches normally. Branching of the zoarium is due to double region of acrogene growth only.

The tabulæ of *Callopora multitabulata* are thin, and the last one is near the cell aperture, and is said to be perforated at the center (*vide* Eastman, *op. cit.*, *f*, 456 *d*). They are nearly always solid. Right here is the chief supposed basis for the interpretation of Trepostomata as Bryozoa. According to E. O. Ulrich's definition (p. 271, Eastman), each tabula was the perforated top of one zoœcium and solid bottom of the next. In fact, the thickened walls here show only that the growth increments lengthening the wall continue on either side downward, thickening the wall, and thence as tabulæ across the cell opening. Further is not seen. Perforate last tabulæ may be incomplete ones.

The characters for distinction of the species are, therefore, mostly visible on the exterior; the shape of zoarium and its branches, shape, size, and shallow depth of the cells, characters of the monticules, the number, size, and shape of mesopores, and thickness of the wall. All these characters vary, and the variation of all should be noted in learning the species. Extremes may be associated on parts of the same specimen.

Prasopora simulatrix Ulr. grew upon some solid surface, at first lens-shaped, later conical (Pl. A, Fig 7), hemispherical, or irregular, expressing slight tendency to acrogene growth, united with moderate established perigene. A short finger-shaped or a branched sporadic acrogene growth occurs sometimes, and this usually at the center. If the colony died off in part, the remaining part then developed, overspreading the old. Even a symmetrical zoarium could develop from the irregular fragment of another. The cells radiate from the flat or concave lower

side to the convex upper one, the lower side being covered, if well preserved, by a thin "epitheca" or coating produced by no one zooid, but by the cortex uniting all. The growth of the epitheca was, of course, marginal. At this margin, close on the epitheca, there was rapid budding of young cells, some of which became quickly full-sized; others became mesopores. At the periphery the cells open obliquely to the zoarial surface. Above it all apertures are more direct.

The number of mesopores in this species (Pl. A, Fig. 8) is so far greater than that of the autocells that relatively few of them can become autocells. They are fewest proportionally in maturer zoaria, and appear to be homologous with those of *Diplotrypa*, only smaller, longer, and, so to say, more permanently mesopores. The numerous small, angular, or impressed mesopores, with shallow openings or calycals, surround the rounded apertures of the thick-walled autocells, making an easily recognized figure at the surface. At intervals occur clusters of cells larger than the average, with more numerous mesopores between them, and thicker walls. They form low monticules, or on weathered specimens high ones. They are areas of rapid cell increase.

The mesopores have numerous transverse tabulæ (Pl. A, Fig. 9). Those of the autocells are numerically proportional, considering the cells' size, but they curve obliquely across, or oftenest form cystiphrams, *i. e.*, the tabulæ in the most regular instances are narrowly beaker-shaped, and are arranged in the cell as nested equal-sized beakers could be in a tube. The flat bottoms have been called diaphragms or tabulæ, the sides cystiphrams. Often the cystiphram extends only partly around the cell, and partly the same lamina is incorporated with the cell wall. Cystiphrams appear to indicate that the zooid body withdrew simultaneously, or nearly so, from the calycal bottom and side, or sides, near the bottom.

The cell wall margins here were not all straight since, *acanthopores* occur. These are minute wart-like structures or thickenings on the cell wall margins, especially at angles, and were

presumably built into corresponding invaginations of the living cortex. They are not cells or pores, but have been supposed to be, hence the name. They are inconspicuous in this species or even wanting, and will be discussed later.

Characters sufficient for the determination are upon the exterior in this as in related species. The peculiar cell pattern can be readily distinguished from structurally very similar ones. The variability in cells, acanthopores, etc., will however be found greater, and there are fewer true species of the genus than recorded. Other species of *Prasopora* have more perigene growth, or, again, acrogene ones are the *Monticulapora*.

Homotrypa minnesotensis Ulr. has long, round, slowly-branching zoarium, with many specific marks as to cells, monticules, etc. Fossil stems are in part or entirely hollow, because the axial region has very thin crenulous walls without tabulæ, hence the sea water could enter and eat away the walls, leaving, if anything, the thicker-walled tabulate peripheral region. The peripheral cell has cystiphrams similar to *Prasopora*.

Batostoma fertile Ulr. consists of large, flattened, or round, somewhat irregularly branching acrogene parts, arising from a large basal expansion of irregular perigene growth. A single basal may support more than one or, again, no acrogene part; but as in *Callopora* a thick walled maturity follows the thin walled, immature stage. Thus the characters of peripheral and axial regions are evident when there is even no acrogene growth. Omitting some details, the peripheral region has thick walls on which are well-developed spines, acanthopores. Mesopores may be very few or, again, very numerous on parts of the same specimen (Pl. A, Fig. 10, *a*, *b*). They are "closed," *i. e.*, their tabulæ built close up to the apertural margin, by which the mesopores, being shallow or confluent, look like closed interspaces merely between the rounded autocells. The cell clusters, which are in place of monticules, have *maculæ*, *i. e.*, clusters of mesopores at their center. The young cells of the axial region

expand quickly, and are scarcely tabulated and very unlike mesopores of the peripheral region, and they are not called mesopores. The mesopores of the axial region are not immature cells but permanently retarded ones.

With this species is conveniently compared *B.*(*Hemiphragma*) *ottawaense* Foord, in which the thin-walled axial and thick-walled peripheral regions are sharply defined, as seen in thin section or in fractured specimens. At the stage when peripheral region is just begun one sees characters very like *B. fertile*, but later the walls thicken more, the mesopores are obscured, closed, or filled, while the maculose-looking monticules show strongly diverging cells, indicating slow growth in cell length compared to width. Acanthopores developed. The tabulæ are peculiar, being often thickened and incomplete, hemiphragms, in the peripheral region. The whole wall in the fossil is corneus looking. They show the result of a decrease probably of calcareous constituent.

Eridotrypa mutabilis Ulr. includes rather small, long, branched, acrogene zoarial parts in which, as seen in cross fracture or section, the cells are larger in the axial region than in the peripheral. The cells turn very slowly in the peripheral region, so that the apertures are oblique to the surface and drawn out anteriorly. Then, as the cells become more direct, the walls increase steadily in thickness, and in very "old" specimens distinctly cup-shaped calycals form (Pl. A, Fig. 11). The thickened wall permits analysis into the bounding edge with its projection downwards, as dividing lamina, and the calycal slope and the main wall below it (*cf.* Fig. 1, *h*, *p.* 21).

Anolotichia impolita Ulr. has irregular large acrogene zoaria, with large cells of quadrangular rather than polygonal outline, and with few mesopores, reminding of *Monotrypa magna* (Pl. A, Fig. 12). The axial and peripheral regions are scarcely distinguished. In the latter stage there are, however, *lunaria* developed. The lunarium occurs in the posterior side of a full-sized cell as a narrow, distended part of the cell. The term lunarium has been applied rather to the lunarial wall, which is narrowly arcuate or crescentic. Where the lunarial and common cell walls join, in

this species, the angles project inwards, as if produced. Moreover the lunarial wall is a little elevated at the surface, making it appear as a distinct wall, but it is really part of the wall deflected and extended. I have searched in vain for the symmetrical crescent that has been figured as the lunarial structure of this species. It appears really to be somewhat irregular, bearing tooth-like points, the downward projections of which appear lucid in thin sections, and are the "vertical, closely-tabulated tubes" described by the author of the genus and species. These same lucid spots in sections crossing calcite-filled cells are very deceptive, appearing like pores. In clay-filled cells they appear clearly as parts of the wall. They interrupt the median wall and confuse in color with the outer laminæ, these lighter parts being also of the same color as calcite infiltration; hence the deception in the fossil.

Fistulipora carbonaria Ulr. is of common, massive growth. Its autocells are rounded, with here and there one having a slight distension, as if a lunarium was developed with minimum distinctness. The autocells are separated by angular, large mesopores in single series, except in the clusters or maculæ, where they are more numerous. The walls around autocells are thick, while those between mesopores are very thin, low, and scarcely above the last tabulæ; hence the appearance is that of isolated autocells with raised "peritreme." Longitudinal section shows the mesopores to have arched, numerous tabulæ, appearing thus as vesiculose filling, or "cœnenchyma" between the autocells. New autocells arise abruptly, displacing one or more mesopores in the midst of mesopores, *i. e.*, "cœnenchymal gemmation."

Stellipora antheloidea Hall encrusts shells, etc., growing laminar or massive, a centimeter thick. The surface is crowded with stellate monticules about 2.5^{mm} wide, each consisting of a central, six to twelve-rayed, depressed, quite smooth, macula, and around this, between its rays, an equal number of ridges which are highest at the inner end and slope outward to the interspace. Sometimes additional ridges occur midway between the outer ends of the primary ones. The maculose

area, as proved by sections, is composed of large, angular mesopores, and the ridges exclusively of rounded autocells, these tending to arrange in two rows, with the walls between the rows a little raised and straightened. The space between monticules is small and occupied by mesopores around a few single autocells, and groups of two, three, four, etc., cells or incipient ridges. In longitudinal sections the close tabulæ only distinguish the mesopores at first, but they soon become vesiculose.

This description is taken from specimens from the "Trenton shales" of the Northwest. The species is very rare as compared to the acrogene ones generally called *Constellaria*.

DISCUSSION OF TREPOSTOMATA

A few species suffice to illustrate the general characters of Trepostomata, and the further detail may be explained by them. In this manner of beginning with a few representative species, proceeding thence to the study of the several characters recurring in the whole group, the perplexing taxonomic definitions may be obviated.

The growth habit or zoarial form is fairly constant in the species, but very various beyond that taxonomic limit. The approximately hemispheric zoarium, with its cells radiating and multiplying with growth from an initial point, may be taken as the central or composite or primitive type. Next, species with an established tendency to grow fastest around the base develop the flattened massive type. Others, more perigene in degrees, connect with the laminate or encrusting, in which perigene growth is near its practicable extreme.

On the other hand, the hemispheric form, by increased acrogene growth tendency, becomes the digitate, and finally dendroid branched. But, as a rule, the acrogene zoarium has a perigene basal expansion, and every degree of form might be pointed out from the conical (Pl. A, Fig. 7), in which moderate acrogene and perigene combine, to the strongly acrogene form, with more or less extremely perigene basal (Fig. 5). As to the basal expansion, it may be massive, laminate to encrusting. It

may in some species support two or more acrogene growths, and in just these cases also the acrogene part may be small or wanting, arguing that the basal expansion might have been the origin of some strictly perigene species, the acrogene part being wholly suppressed. The laminate form may have again become massive. Finally, an acrogene growth may be round, compressed, flattened, frond-shaped, or bifoliate. In short, the series between zoarial forms is very complete, and genetic relationship between the most extreme forms may be presumed. The lines of evolutionary development have never been traced, however, and they evidently cross or parallel in a confusing manner; hence this character is of taxonomic use in species chiefly.

The different zoarial forms result not from changed shape and size of the component cells, as one can readily observe in similar zoaria of extremely different cells, but, as seen firstly in variations of a species, it results from increase of cells, the region of greatest cell increase being that of greatest zoarial growth, and inversely. The change of zoarial form, nevertheless, must be made to explain the change of cell as seen in different regions in the same species. Thus, in the acrogene growth, where the cells are turned from the axis of rapid growth to the peripheral slow growth region, it changes markedly, becoming thick walled, closer tabulated, etc. (Pl. A, Fig. 6, *c*). Noticing that the cell apertures do not spring apart under any circumstances, and presuming that this is because the respective zooids were bound together by a cortex, it can be understood how the same cell can be different in two parts, and why there are certain differences in cells. Thus, the tip of an acrogene zoarium, like a hemispheric or massive zoarium, has the cells subparallel, lengthening as new cells develop, so that the surface or circumference widens and the radius or cell-length increases proportionately. But as a cell turns into the peripheral region it comes into a zone of more restricted circumference and radial lengthening; hence the cell is shorter, thicker-walled, and closer-tabulated. Moreover, the cell-increase lessens to some degree, which further restricts the circumference and radius with added effect. In the

latter way the apex of branches often retarded building thick-walled and close-tabulated cells, and sometimes the basal expansions did likewise; and it is evident then that a kind of zoarial maturity exists, simulating if not derived from the "peripheral" stage. Further, specimens in which a mature stage has developed at the apex may renew axial growth and cell characters, a second maturity following, by which it would seem that environmental causes have had to do with the time of maturity.

In a specimen of *Eridotrypa mutabilis* Ulr. at hand, a fortuitous branch has arisen from the mature region instead of the axial, and consequently a cell can be traced as axial, peripheral, axial, and peripheral again. Injured or broken zoarial parts are commonly renewed by thin (axial) cell growth, even in the peripheral region, a stolon-like expansion first overspreading the dead area. In perigene growth also the young cells arising at the margin are at first more prostrate than later, giving rise to a basal stolonal region, and in thin, laminar, or encrusting forms it is very distinct. In these cases the stolonal has been said to be probably the homologue of the axial immature region of dendroid zoaria. The stolonal and immature regions in these may coincide, but it is wrong to assume that they do in other and all cases. The stolonal part need not be considered as coördinate with the developmental peripheral and axial regions. It seems, in fact, unnecessary to attach any genetic significance to the stolonal region further than that it is incidental to perigene growth.

In a given species one specimen larger than the other may be so either from more vigorous growth, as seen in larger axial or immature region, or from longer continued growth, as seen in thicker peripheral or mature region.

Cell increase is, as a rule, intermural, *i. e.*, young cells begin as small, round pits in the wall at the angle between three or more older cells. The reproduction or budding of zooids doubtless took place in the cortex above the zoarial skeleton, and only later the young zooid comes to build a cell, which, however, from its initial, has its own wall, *i. e.*, wall-half. The young cell

becomes triangular, quadrangular, etc., in proportion as it grows large enough to neighbor on three or more cells. Young cells have shallower calycals and are generally closer-tabulated, but proportionate to their size, as compared to mature ones. The number of young cells in proportion to large ones affects the cell pattern at the surface. This is especially notable when the simplest case of rapid, direct, continuous expansion of young cells is contrasted with that where "mesopores" are numerous (Plate A, Figs. 1 and 10).

Mesopores are said to be present if the young cells when about half-grown in diameter, retard or cease their expansion, but, of course, continuing length growth. If the mesopore stage of cell is short, few mesopores, if long, many mesopores, are present. They may outnumber the autocells so greatly that a small proportion only could become autocells. They may be more numerous in the peripheral, mature, or retarded cell growth region. Again, as in *Prasopora simulatrix* many mesopores remain such while other newer ones develop to autocells. Yet, apparently any mesopore may finally become autocell. They are, however, something more than retarded young cells, in case like *Stellipora* (*Constellaria*), where the angular mesopores are rather larger instead of smaller than the rounded autocells.

The more distinct the mesopore development the more subordinate they appear to become. The autocells are angular from contact with each other or young cells, but rounded when crowding mesopores, the latter alone remaining angular. Also the mesopores become shallow, the tabulæ developing close to the wall margin forming "closed" mesopores, or they even filled solid with superimposed tabulæ; or the tabulæ overlap the walls, forming "vesiculose" structure. Autocells arise, displacing several mesopores at once, "cœnenchymal gemmation," in some species with vesiculose or even regular mesopores.

Monticules, as Nicholson pointed out, are rapid cell increase areas. In simplest cases they appear at the surface as mere small elevations or more or less elevated clusters of slightly larger sized cells, among which young cells are seen except

rarely in a growth retardation stage. A few young cells or mesopores are present, or many mesopores, or again aggregated mesopores between the cells are found in some species, or exclusively mesopores form maculæ or large aggregates in other species, with or without surrounding major-sized autocells. The elevated clusters are the typical *monticules*. The extreme degree of elevation is expressed by the name monticule. Maculose ones or "maculæ" are nearer plane or slightly depressed. Exceptionally a typical monticule may extend like a ramulet, in which case it is probably to be considered as such,—a fortuitous acrogene growth having sprung from the area of one monticule as it might also have from that of several.

The monticules are distributed on the zoarial surface more or less regularly, new monticules arising from the widening intervals, and never, apparently, one monticule from another. The function of the zooids that built the major autocells is unknown if it was different from that of others. The only discernible peculiarity of the monticules to which a special function could be assigned is their more rapid reproduction or cell increase than the interspaces. In this respect they resemble the acrogene growths or the axial region, and when very prominent they might suggest an origin as retarded branches, but no unquestionable transitional forms to these are known to me. They differ from branches in their size and in relation to the zoarium as a whole; for, if monticules produce the more new cells, their interspaces produce the less, the zoarium being unchanged; while, on the contrary, growth of branches comprises essentially the zoarial growth as well as the maximum increase of cells.

The surface pattern, as shown, is very diverse. The average size of cells in a species is quite constant, but in different species differs several diameters. The form of aperture, quadrangular, polygonal, to rounded; the relative size and numbers of young cells and mesopores; the monticules and maculæ of varied style; all these form conspicuous essential characters by which species can be recognized. The calycals, too, are deep

or shallow, relatively, in different species. The autocell walls, which are thin and then more or less thickened, give respectively polygonal or rounded calycals, since the thickening is greatest at the cell angles. A beveled wall edge or impressed rim around the cell aperture gives it in many a saucer-shape, especially when the walls are very thick (Plate A, Fig. 11).

Acanthopores or warts may be present on the walls, usually at cell angles. A lunarium, when present, gives the cells another peculiarity. The lunarial wall and the acanthopores are, however, mural modifications, and will be explained in that connection later.

Thin section is quite necessary to bring out the wall's structure. The walls are dense. If thin they may show no differentiation; yet, if a specimen split, the cleavage may pass longitudinally and so as to leave part of the wall attached to each stone core, which fact has been taken to indicate that the wall is always structurally double! Presumably the wall is built double always, *i. e.*, the increment on the margin is continued within every calycal, the wall being thus double with a median, third part, which is, however, not known to be double. A thickened wall tends to show greater differentiation, both in structure and composition, than a thin one. The median wall may appear either distinct or not, and correspondingly the striping parallel to the wall's surface when seen, showing the laminæ of growth, is either interrupted by the median wall or more or less distinctly crosses continuously from one side wall to the other.

To explain the structural aspect of acanthopores in thin sections, the following analysis may serve. A distinctly double wall shows the median wall as a line in transverse section (Fig. 1, *a*) and when the wall edge is scalloped (Fig. *b*) the median line appears interrupted in section (Fig. *c*), corresponding to the angles. A rounded wart (Fig. *d*) would produce a similar effect (Fig. *e*); or, if very distinct, as in Fig. *f*. When once begun, the wart may have its own growth, so to say, independent of the wall thickness (Fig. *g*), becoming so large as to appear

to have displaced a young cell or mesopore. Such a large acanthopore inflects the cell wall, forming a vertical rib or pseudoseptum as a rule. No doubt the acanthopore end, or wart on the wall, extended to fill an invagination in the web or cortex which bound the zooids to which the cells belonged. Explanation of the cause of such invagination need not be attempted here. But it may be added that the walls were evidently built by surface secretion, and that the growth of a projecting wart would be accumulative as compared to a plane surface, other things being equal. This may explain why acanthopores are

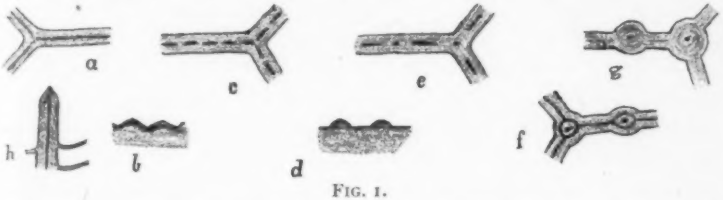

FIG. 1.

often so independently large. A scalloped or saw-edged wall would not develop so. The transverse of a wall would, however, if the zooids and cortex did not draw upwards fast enough to prevent it. Thus a wart thickens in two dimensions to the wall's one. Since, however, the wart is on the wall, it receives below the wall thickness also, and hence acanthopores might well be four or more times the thickness of the wall from result of secretion alone. In fact, it is necessary to explain why the walls, etc., can be very thin, which is evidently because the zooids drew forward rapidly.

It is fair to presume that structural differentiation of the wall may be accompanied by difference in composition; and that may explain why the elevated lunarial wall may be different colored and textured than the main wall; or, again, lucid vertical lines or "lunarial tubuli" only are different, these being the vertical extensions of tooth-like elevations on the lunarial wall margin. Acanthopores show similar differences. Such structures might be mistaken for mural pores in thin sections. Mural pores do not occur.

Tabulæ perhaps need no special mention; their character as the successive bottoms of the calycals is entirely evident (Plate A, Fig. 2, and Fig. 1, *h*, p. 21). In structure, if any be seen, they are one-sided. E. O. Ulrich has observed the very rare occurrence of perforation or circular opening in the last tabula, which he interprets to prove that all other tabulæ are double, comprising the amalgamated cover of one zoœcium and bottom of a next superimposed zoœcium. In absence of any substantiating evidence it is better to take the most direct explanation, which would be that the observed perforated tabulæ were left incomplete by the death of the colony. Indeed, in *Hemiphragma*, the tabulæ of the cells in the peripheral region are all left incomplete or were imperfect as to calcareous structure. The surfaces of tabulæ are sometimes papillated, and these again, like the acanthopores, simulate perforations in the fossilized specimen.

As a rule, neighboring cells do not have corresponding tabulæ, either in position or number. In any species or individual they are approximately regular in position and numbers, but never quite so. In different species the number ranges in extremes from none, as seen in the axial region of some species, to very many in others, or even to a compacted papillose mass filling the cells, or especially the mesopores in some thick-walled forms. There is no unit form and size of loculus assignable, which argues very strongly against any theory that the successive loculi represent superimposed zoœcia. The clearer interpretation is that each cell was built by one zooid. Tabulæ are, as a rule, very thin; and tabulæ wanting and tabulæ thickened are opposite degrees. Individual variation and specific difference in number and thickness of tabulæ may be ascribed to difference of growth and to secretion of substance. Difference in form, such as the cystiphrams (*Prasopora*), are ascribable to shape and size of the zooids' base; and vesiculose mesopores, to shallow or closed calycals from short zooids, and to their shifting, possibly, also.

AFFINITIES OF TREPOSTOMATA

Regarding the affinities of the Monticuliporoidea as a whole, the evidence uniting these to the Bryozoa on the one side, and to Tabulata or Alcyonarian corals on the other, does not lead to a compromise conclusion that they really were related to both as an intermediate or connecting link, because, as will be seen, the interpretation of the zoarium necessary to unite them with the one is discordant to that necessary to unite them with the other; and because of evidence to the contrary from the embryology of living Bryozoons and corals. Discussion is therefore confined to the question whether the extinct Monticuliporoidea are Bryozoa or Cœlenterata.

In relation to Bryozoa, the problem begins with the Trepostomata section, some or all of which have been variously and doubtfully referred to Cyclostomata; and this order of Bryozoa is extant. The reference involves comparison with the supposed Cyclostomatous genera *Neuropora* and *Heteropora*, of which we are yet uncertain. Gregory[1] refers these as typical Trepostomata, not Cyclostomata. The question rests mainly upon the fossil and recent *Heteropora* which Nicholson[2] has thoroughly discussed and which, as it appears, simulates Trepostomata, but has many transverse mural pores and other differences. Trepostomata must therefore be proved to be Bryozoa and *Heteropora* likewise to belong to Trepostomata, before they can be united with assurance. Gregory's reference needs proof and affords no evidence, but expresses well perhaps that we are uncertain of all. Passing to the comparison of Trepostomata with undoubted Bryozoa, this requires knowledge of the extinct Cryptostomata, which must in turn be compared with Bryozoa; and discussion of that part of the problem will therefore be deferred to the section on Cryptostomata.

In relation to Tabulata or Alcyonarian corals, Trepostomata may be compared immediately. In the first place, such forms as *Monotrypa* compare with *Chætetes*, a massive zoarium of small,

[1] Catalogue of Jurassic Bryozoa, p. 193, 1896.

[2] Structure and Affinities of the Genus Monticulipora, p. 62.

tabulated, thin-walled, polygonal cells. *Chætetes* has comparatively lighter colored, probably more calcareous walls. Its cells increase only by fission, while intermural "budding" obtains in *Monotrypa*. It is said, however, that fission occurs rarely in Monticuliporoidea, which leaves a difference in degree only between these two. *Chætetes* is extinct, but is referable only as a coral. It indicates that the *Monotrypa*, *Monticulipora*, etc., are corals; but that the family *Chætetidæ* should contain *Monticulipora* seems doubtful when *Fistulipora* is placed in a family of its own.[1] Certainly *Prasopora* does not belong in both.

Fistulipora, which is the extreme form of Trepostome as compared to *Monotrypa*, is the very one most approaching the Recent coral, *Heliopora*, which, as shown by Mosely, is an Alcyonarian, with a true tabulate skeletal structure. *Heliopora* has the larger cells, but like *Fistulipora* has autocells among mesopores, called siphonopores. The autocells increase by "cœnenchymal gemmation," *i. e.*, a young autocell arises among siphonopores, displacing several. Siphonopores and mesopores are alike. Also, in the mature region of *Heliopora*, the walls thicken and a wart-like projection stands generally at the siphonopore angle and twelve of them surround the autocell. Structurally the warts are similar to "acanthopores," but the wall of *Heliopora* is highly calcareous, and in thin section one sees primarily the crystalline structure radiating from the normal line or center, while the Monticuliporoid wall, being apparently less calcareous, shows the organic lamination, and the acanthopores have concentric structure. The difference is referable to the degree of calcareous deposit in which all corals differ. The warts on *Heliopora* are due to transverse canals between zooids swelling the cortex unevenly. Acanthopores might well be of like origin, and if so they indicate a canal system like that in Alcyonaria.

It has not been clearly enough understood that Mosely[2] demonstrated the *Heliopora* to have no mesenterial septa, but that twelve vertical ribs in each autocell are pseudosepta; and

[1] EASTMAN, op. cit., pp. 102, 103. [2] Challenger Report.

as such they can be compared exactly with the inflections produced by acanthopores in many Monticuliporoids, if the small difference in calcareousness of skeleton be considered. More calcareous ones have sharper processes. A lunarium is wanting in *Heliporidæ*, but this structure is absent in *Fistulipora* in part, and in most Trepostomata. Any structural differences between *Heliopora* and *Fistulipora* are found further in some genus or other closely related to the former, except the monticules or maculæ of the latter.

If one places all Trepostomata and the Tabulata (Alcyonaria) together, they are compared as follows: The largest cells of the former are scarcely equal the smallest autocells of the latter. Growth habit is alike. Cells, monomorphic or dimorphic, are alike; except that distinct pseudosepta in autocells are common in Tabulata, being absent in few cases and these when the walls are very similar in structure to that of Trepostomata, *i. e.*, when crystalline radiate striping is absent,—except also that mural pores cross the walls of many Tabulata, not, however, in dimorphic forms nor in monomorphic ones with small cells,—except again, the lunarium of Fistuliporidæ and the so-called dorsal septum of Alveolitidæ. Notably, the two lunarial angles, forming two pseudosepta, are on the upper side in the former, the single "septum," pseudoseptum, is on the lower side in the latter; the structures therefore not corresponding. If, however, they be ascribed respectively to the double ventral folds and the single dorsal fold of certain Alcyonarian Recent corals,[1] one finds them all represented in Cœnites, a Paleozoic tabulate coral. They are rarely indicated in skeletal structure of either Monticuliporoidea or Tabulata, but argue Alcyoranian affinities.

Cell increase is not unlike. In the Tabulata (Alcyonaria) it is by fission, unequal fission, stolonal gemmation, and intermural gemmation, which are probably degrees of transformation.[2] Intermural gemmation is the rule in Trepostomata. The peculiar

[1] See further, Neues Jahrb. Minn. Geol. and Pal. Beilb. X, pp. 316, 320.

[2] See op. cit., pp. 281, 359.

cell development known as cœnenchymal gemmation occurs in both, and they are not distinguished.

But Trepostomata generally have *monticules* or maculæ, which Tabulata never have; and tl.erein is the one important distinction. But this also argues their relationship, for the Tabulata, comprising three divisions, can be held as the Paleozoic ancestors and representatives of the Alcyonaria as to three of four divisions respectively, the fourth having no known ancestor, unless the Monticuliporoidea be so considered.[1] Among those of the fourth division *Renilla et al.* show a budding and grouping of the dimorphic zooids similar to or like that which must have obtained in the monticulate *Prasopora et al.* The absence of tabulate skeleton in *Renilla* would be explained as in the case of other Alcyonaria, and need not be recounted here. The supposed relation of Monticuliporoidea and Pennatulidæ I formerly considered as based on deduction and slight evidence, and the explanation of monticules is corroborative.

These same monticules and maculæ, on the other hand, bind the Monticuliporoidea together, *i. e.*, Trepostomata to Cryptostomata. In the preceding paragraphs the relation of Trepostomata to Alcyonarian corals is discussed without the Cryptostomata, but these would not change the argument as given if included. They are generally supposed to be Bryozoa, and are important to that side of the question which will be given later. There is in fact no character in the Monticuliporoidea to separate them from the Tabulata, corals. Their separation, if accomplished, would rest upon stronger evidence binding them to undoubted Bryozoa.

EXPLANATION OF PLATE A

FIG. 1. Monotrypa magna Ulr., cell pattern. × 10.
FIG. 2. Monotrypa magna Ulr., vertical section of cells. × 10.
FIG. 3. Diplotrypa limitaris Ulr., cell pattern. × 10.
FIG. 4. Diplotrypa limitaris Ulr., vertical section. × 10.
FIG. 5. Callopora multitabulata Ulr., a small zoarium, natural size.

[1] Op. cit., p. 349.

FIG. 6. Callopora multitabulata Ulr., *a*) cell in axial region, *b*) vertical of same, *c*) vertical showing peripheral cell region, *d*) cell pattern of peripheral region. × 10.

FIG 7. Prasopora simulatrix Ulr., zoarium, natural size.

FIG 8. Prasopora simulatrix Ulr., cell pattern. × 10.

FIG. 9. Prasopora simulatrix Ulr., vertical section. × 10.

FIG. 10. Batostoma fertile Ulr., *a*) cell pattern × 10, and *b*) surface. × 20, showing mesopore' stabulaæ.

FIG. 11. Eridotrypa mutabilis Ulr. surface × 20, showing calycals. After Ulrich.

FIG. 12. Anolotichia impolita Ulr., cell pattern. × 10.

FREDERICK W. SARDESON.

MINNEAPOLIS, MINN.,
November 5, 1900.

THE EXCURSION TO THE PYRENEES IN CONNECTION WITH THE EIGHTH INTERNATIONAL GEOLOGICAL CONGRESS

THE origin of the ancient crystalline rocks of the earth's crust is a subject which has always possessed a peculiar interest for geologists and which, now that the progress of investigation seems to bring the solution of the various problems connected with these rocks almost within our reach, has a greater attraction than ever.

One of the most important lines of evidence bearing upon this question is that derived from the study of the contact zones about intrusive masses, but the effects produced by many of these intrusions have been differently interpreted by different observers.[1] In France especially, Michel-Lévy, Barrois and Lacroix have described intrusive granite masses, which have not only intensely altered the strata through which they pierce but which have produced a wholesale transformation of the sedimentary rocks in question into granite, the granite now occupying the space formerly occupied by the sediments. If this be the origin of granite, a knowledge of the fact would have an important bearing on the interpretation of many occurrences in the Archean, but the great majority of geologists have been unable to find evidence of it in their respective countries. The French Pyrenees have, however, been cited by Lacroix as a district in which these remarkable transformations could be seen with especial clearness, and in connection with the International Congress of Geologists held last summer in Paris, an excursion to the Pyrenees was accordingly arranged, under the leadership of Professor Lacroix, in order that the members of the congress might have an opportunity of seeing these transformations in the district made classic by Professor Lacroix's work. It is proposed in the present paper, first

[1] ADAMS, F. D.: A review of some recent papers on the Influence of Granite Intrusions upon the Development of Crystalline Schists. JOUR. GEOL., Vol. V, 1897.

to give a short account of this excursion and then to discuss briefly some points in connection with the explanations offered by Lacroix of the phenomena observed.

Leaving Paris on the morning of August 3d on our way south to the rendezvous of the excursion at Ax-les-thermes, the great Tertiary plain of northern France was first traversed. The country as far as the eye can reach is quite flat and excellently cultivated. The grain had just been cut and stacked, and the country in appearance afforded a marked contrast to those portions of the southeast of England underlain by rocks of the same age, in the entire absence of the picturesque hedges and of standing timber. The train then gradually ascended the table land of the Plateau Central, from which far to the east rose the volcanic peaks of the Auvergne, and the country assumed a more rolling character. Descending from this plateau on its southern side over strata of Jurassic age, past Brive and Souillac, the landscape underwent still another change, the country becoming in many places rough and broken, with great exposures of bare rock on either side, through which the train threaded its way in numerous tunnels and rock cuttings, and as the night closed in reached the old city of Montauban. Next morning, passing over the Tertiary basin of southern France, through Toulouse and up the wide low walled valley of the Ariège, Foix was reached, about which place the valley narrowed and the foothills of the Pyrenees rose high and abrupt on either side. Thence passing on by Tarascon the train reached Ax-les-thermes, a picturesquely situated little town, lying well within the Pyrenees, whose hot springs and baths annually attract a large number of visitors, chiefly from other parts of France.

Here the members of the congress who were to take part in the excursion, twenty-eight in number, coming from various parts of Europe and America, were received by Professor Lacroix. Five of the party only claimed English as their native language; Mr. Arnold Hague, Professor Wolff and Dr. Ries representing the United States, while Mr. Kynaston, of the Geological Survey of Scotland, represented the United Kingdom.

The following day, August 5th, the regular work of the excursion began, two visits being made, from Ax-les-thermes as headquarters, on consecutive days, to the contact of a large mass of granite, several miles to the northeast of Ax-les-thermes in the heart of the Pyrenees, with a series of shales and limestones believed to be of pre-Cambrian age. The exact age of the granite is not known but it is younger than the Carboniferous and older than the Lias.

The contacts seen on the first day, were chiefly in the vicinity of the beautiful little L'Etang de l'Estagnet, from which there rise on either side great walls of bare rock, and well graded talus slopes affording abundant exposures. (See Figure 1.)[1] The normal granite of the district is light in color, poor in iron magnesia constituents and contains large porphyritic feldspars. It often shows marked evidences of dynamic action. The shales near the contact are hardened, being converted into a hornstone, said by Lacroix to be in many places "feldspathisé," but the most interesting feature of the excursion was the contact of the granite with the limestone. This limestone, which is gray in color and highly crystalline, contains many little bands of silicates, representing impure laminæ in the original rock, which, especially on the weathered surface, emphasize its stratified character in a most striking manner and often display the most complicated contortions. The limestone in its whole character and appearance exactly reproduces many occurrences seen in the more altered limestones of the Hastings Series in the Archean of Canada.

Between the limestone and the granite, however, there is a zone of rock, often very narrow but in some places, according to Lacroix, as much as 800 meters wide, more basic than the granite and termed by Lacroix, "Diorite" or "Roche Dioritique." This completely surrounds certain isolated occurrences of limestone and is believed by Lacroix to have been produced by the

[1] For the photographs which illustrate this paper, with the exception of that reproduced in Fig. 2, the author is indebted to Professor Heinrich Ries, of Cornell University.

granitic magma, before crystallization, dissolving a portion of the lime-stone, incorporating it, and thus being rendered more basic, crystallizing out as a diorite about the contact. This "Roche Dioritique," while as a general rule tolerably uniform in appearance, often presents rapid variations in size of grain from fine to coarse, and in other places passes into more basic forms such as norite and even into varieties holding olivine.

The excursion of the second day took the party to another portion of the periphery of the same granite mass in the wild district about the L'Etang de Baxouillade (see Fig. 2) and the Cirque de Camp Ras. The route followed led first over the granite, which as the contact was approached was seen to hold a few dark inclusions, which certain of the petrographers present at once set down as basic secretions from the magma. These, as the little L'Etang de Baxouillade was passed become more numerous and often presented the appearance of having been softened and drawn out. Further on at the Cirque de Camp Ras the granite comes against a mass of shale interstratified with limestone. Both of these rocks are highly altered, the shales being converted into dark hornstones and the limestones into paler lime hornstones, consisting chiefly of a basic feldspar and pyroxene. Along the immediate contact of the granite, there appears to be evidence that the dark inclusions before mentioned are masses of hornstone which have been separated from the walls, caught up by the granite magma and more or less softened —or in the case of the lime hornstone dissolved, giving rise to irregular shaped masses of the "Roche Dioritique" before mentioned. One block of gneissic granite about two feet long was observed, at one end of which, embedded in the granite was a mass of the light-colored hornstone enclosing a mass of unaltered limestone, while at the other end of the same block, the granite contained small masses of "Roche Dioritique," which certainly presented the appearance of dissolved fragments of the same limestone. The only other explanation of the origin of these darker-colored masses in the granite is that they are basic secretions from the granite magma itself, about the margin of the mass,

but the appearances in the field rather favor Lacroix's interpretation.

The next day the party, leaving Ax-les-thermes, drove to Foix, visiting on the way the gypsum quarries near Tarascon. The gypsum is of Triassic age and is seen to have resulted from the alteration of anhydrite. It contains intercalated marly beds holding dipyre, tourmaline and other minerals, which are believed to have been developed in them by an intrusion of ophite, which however is not exposed in the immediate vicinity.

On August 8th a visit was paid to a great mass of "Cipolin," intercalated in the gneiss near Arignac, which is locally rich in various minerals of the humite group and containing also spinel, plogopite, rutile, etc. The name "Cipolin" is given by the French geologists to any crystalline limestone intercalated in gneiss, even although it be free from the micaceous minerals which give to the typical "Cipollino" its distinctive character. This mass is from 200 to 300 meters wide and is identical in character with the limestone found in many parts of the Laurentian in North America. The enclosing gneiss is said by Lacroix to contain garnet, and also to differ somewhat in other respects from the granite of the vicinity of Ax-les-thermes. Its origin is unknown.

In the afternoon other large exposures of crystalline rocks near Cabre were visited. These consisted of epidosite, quarried for road metal, containing large lumps of malacolite in places and traversed by little graphite seams. This epidosite is believed to be an altered limestone, and is interstratified with bands of a peculiar dark fine-grained micaceous gneiss, exactly like that which is so uniformly associated with the limestones of the Laurentian in Canada and in the Adirondacks. The age of these crystalline rocks has not as yet been determined.

In the evening the party reached Vicdessos, some seventeen miles west of Ax-les-thermes, a most picturesquely situated little mountain village, from which excursions were made on the two following days. Our route on the first of these days led up to the quaint little village of Sem, where the renowned iron

mines of Rancié were visited. The deposit here consists of a large body of limonite of irregular shape, enclosed in Silurian limestones and shales, and nearly coinciding with them in dip. It is worked by a series of levels the lowest of which is at Sem. This ore body which is very extensive has been mined for ages and formerly supplied ore to as many as fifty Catalan forges, which were in blast in the vicinity. The ore which is handled in a rather primitive manner is now sent to Tarascon, where it is smelted in the blast furnaces situated there. The limonite which makes up the mass of the deposit that has been worked up to the present time, is derived from the alteration of spathic iron ore into what the ore body changes in depth.

Taking a little path up the mountain beyond Sem, a summit marked by the Croix de Ste. Tanoque was reached, where an occurrence of lherzolite is well exposed. This is the original locality of the "Lherzoline" or "Lhercoulite" of Cordier, who mistook the somewhat altered and serpentenized rock for a distinct variety, to which he gave this name. The Jurassic limestones are here penetrated and altered by the intrusion, being bleached and crystallized, while the blocks of the light colored dipyre hornstones found near the contact are considered by Lacroix to be impure or marly bands which were interstratified with the limestones and which by virtue of their peculiar composition were able to fix the exhalations from the lherzolite, which the limestone was unable to do, and in this way to yield a rock rich in dipyre, microline, orthoclase and a variety of other silicates, the original differences in the composition of the beds becoming accentuated through the action of selective metamorphism.

Leaving Vicdessos the following morning, the party traversed the forest of Freychinède, climbing up great exposures of the Jurassic limestone, blue in color and often brecciated, the color being bleached out in spots and streaks precisely as in the Jurassic limestones of the Alps. In these limestones are several occurrences of lherzolite and ophite, which according to Lacroix have the form of laccolites, and which alter the limestones

as described in the case of the occurrences near the Croix de Ste. Tanoque. Passing out of the forest and over the high pastures of the Col de Massat, where a number of shepherds and and cowherds in their picturesque dress were met, the party descended to the renowned L'Etang de Lherz, a beautiful little tarn, by the side of which the original lherzolite is seen. Here a great mass of this rock, dark brown on the weathered surface, penetrates the Jurassic strata, forming by far the most important occurrence of lherzolite in this portion of the Pyrenees. After lunch by the shore of the lake, the mist which had been gathering during the morning settled down as rain, and the party were obliged to hurry on to Massat, the "chef-lieu" of the canton, one of the most secluded little places in the Pyrenees, and one of the few places where the peculiar local costumes of the peasants of the Pyrenees still survive.

From Massat, early on the morning of August 11th, the party drove to Saint-Girons, stopping on the way to examine two or three ophite occurrences and at the Pont de Kerkabanac to see a contact of granite with schist. On the rocky bank of the little stream at this point the granite is seen breaking through the schist and including many little fragments of it. These are often angular, but in some cases appear to have been softened and somewhat drawn out. The "granitization" of these schists was said to be particularly pronounced. The appearance of the contact, however, was like that of any other ordinary granite contact, where the igneous rock has broken through a shattered mass of shale, caught up the fragments and baked them intensely.

At Saint-Girons the train was taken to Bagnères-de-Bigorre, another locality in the Pyrenees renowned for its thermal springs and hot baths, where during the afternoon the party visited the museum of Mr. Charles Frossard, rich in collections illustrating the natural history of the Pyrenees, after which they inspected the extensive marble cutting works and the baths.

About two miles from Bagnières-de-Bigorre is Pouzac, the well-known nepheline syenite locality. This rock, together

with two masses of ophite, is exposed by the side of the railway line, cutting a series of limestones interstratified with marls, which is supposed to be of Triassic age. But little can be seen of the mutual relations of the several rocks or of their contacts. Lacroix states that the nepheline syenite and the ophite appear as little masses penetrating the Triassic limestones. He thinks the nepheline syenite is later in age than the ophite, which seems to surround it, but there appears to be no evidence from their field relations which makes it improbable that they are differentiation products of the same magma. The occurrence of the nepheline syenite, from which all the Pouzac material in collections the world over is derived, is barely sufficient in size to furnish a working face for a single small quarry. (See Fig. 3.) The rock is much decomposed, the sandy disintegration product being used for repairing the roads in the vicinity, but fresh material may be obtained from the numerous bowlders of decomposition. Small bostonite dikes occur in the limestone near the contact. The marly beds are filled with dipyre and the limestones contain little albite crystals, both minerals being attributed to the metamorphosing action of the ophite. The ophite itself is in many places filled with dipyre, which is, however, believed by Lacroix in this case to be the result of weathering.

On leaving Bagnières-de-Bigorre the party drove up the valley of Campan to Payole, a remote hamlet in the mountains, near which a quarry has been opened in a marble of Devonian or Carboniferous age, the stone being sent to Bigorre to be sawn and polished. The rock, which is known as Marbre de Campan, has a reddish or a grayish color and a linear brecciated structure, which produces a handsome effect on the polished surface, and which appears to be caused by certain laminæ in in the rock, rich in carbonate of lime, breaking apart under the pressure to which the rock has been subjected, while the intervening laminæ, rich in argillaceous matter and more plastic, have been forced in between the calcareous fragments and now cement these together.

One of the most interesting granite contacts seen on the excursion was reached from Payole, that, namely, of the Cirque d'Arbisson. Leaving Payole early in the morning on August 13th the party made their way through the Bois d'Arreiou-Tort and up over the moraines mantling the valley bottom and the lower slopes, and after several hours climbing reached the foot of the great Cirque. But little rock is exposed on the way up, but at the Cirque itself, whose walls tower up in the form of a great amphitheater of bare rocks skirted with talus piles, the exposures are magnificent. (See Fig. 5.)

The rocks composing the Cirque are Upper Devonian in age and consist of thinly banded strata, greatly contorted and twisted, and now converted into hornstones of several kinds, varying in character with the original composition of the rock. The unaltered rock was not seen, but it would seem to have been not unlike that worked in the quarries near Payole. The argillaceous bands, however, were probably more numerous and some of the bands were highly siliceous. The contortions and the breaking apart of the harder bands with flowing of the relatively softer layers, in this case the limestones, between the fragments is excellently seen. (See Fig. 6.) The original marly beds have been converted into epidote hornstones, while the more siliceous beds are converted into a flintlike material which is much darker in color. Some of the limestone bands, although greatly contorted, have retained their fine-grained texture and blue color, but owing to the shearing movements to which they have been subjected they have assumed, as is frequently the case in such occurrences, a sort of schistose structure. The limestone, however, is usually traversed by little streaks, coarser in grain and whiter in color, marking the first stage of a recrystallization and passage into marble. The limestones or calcareous bands in places contain large crystals of red garnet, resembling the well-known occurrences on the Stikine River, although the development of the crystals is not so perfect. Beautiful flat rosette-like groups of vesuvianite crystals also occur in places along the bedding planes, usually between the layers of epidote

hornstone and the more siliceous bands. A few granite dikes and a mass of granite, apparently of comparatively small dimensions, occur on one side of the Cirque, while the other side is free from granitic intrusions. In these dikes, and also in the hornstone near the contact, axinite occurs in masses of considerable size. In the dikes this mineral occurs as rather coarsely crystalline streaks, in some cases on the walls and in others within the dike itself. In the hornstones it occurs as an impregnation, apparently partially replacing the other constituents of the rock. The petrographical character of the various rocks can be well seen in the immense talus piles at the foot of the cliffs, which also afford an excellent opportunity for collecting. From a petrographical standpoint this was one of the most interesting localities visited on the excursion.

The excursion, as originally planned, was to have terminated here, the party returning to Bagnières-de-Bigorre and then taking the train to Paris; but the majority of the party willingly accepted the proposal made by Professor Lacroix to extend the excursion by another day and visit Barèges. Accordingly, they left Payole on the morning of August 14th, and drove to Gripp, and thence walked to the Col du Tourmalet, over a great series of highly inclined and more or less altered clay slates, limestones, etc., of Upper Silurian and Devonian age. Magnificent views of the Pic du Midi, the highest point of the French Pyrenees, were obtained at a number of points along the route. The ascent was long, the day very hot, and shade by no means so abundant as could have been wished, but the Col du Tourmalet was at length reached, and the very abrupt descent made into the valley of the Bastan, over magnificent rock exposures. The granite appears near the head of this valley, and at its contact with the stratified series there appears a mass of rock consisting of a mixture of actinolite and axinite. The contact was not seen by the writer, but Professor Wolff, who saw it, states that the margin of the granite seemed to be well defined, although somewhat melted into the actinolite axinite rock above mentioned. As the evening was closing in, however, there was

not sufficient time to make a study of the relations of the intrusion, the party being obliged to press on to Barèges.

The valley of the Bastan, in which Barèges is situated, is an excellent example of a valley half filled with morainic material, which is now deeply trenched and for the most part removed by the present stream. Patches of the moraine still remain adhering to the sides of the valley high above the present stream level. Great spaces swept bare by avalanches, here so destructive, can be seen at intervals, and high up on the steep slopes the terraces built by the French forestry department and by them planted with trees to prevent the snow from moving on certain of the more dangerous of the upper slopes, and in this way to avoid a repetition of the disastrous avalanches of former years.

At Barèges the excursion was brought to a close. The majority of those taking part in it, having on the following morning inspected the mineral springs for which the locality is renowned, left for Paris on the afternoon of August 15th, while a few members extended it by still another day and made a visit to the Cirque of Gavarnie, at the head of the Gave de Pau on the Spanish boundary, which is certainly one of the grandest spectacles in Europe, suggesting somewhat the great cliffs of the Yosemite valley (see Fig. 4).

The excursion was planned with the greatest care, and all the arrangements were personally supervised by Professor Lacroix, to whom the sincere thanks of the excursionists are due. Sleeping, as the party was obliged to do almost every night, in some remote mountain village, which was usually taxed to its utmost capacity to accommodate such an unusual influx of visitors, it was very difficult to make satisfactory arrangements in every case. Whatever comfort was to be had, however, the party enjoyed, and the excellent weather contributed greatly to the success of the excursion.

In entering upon a critical discussion of the phenomena observed, the writer feels that great care must be exercised in forming a judgment from what was of necessity a rapid and

more or less incomplete study of the several occurrences. The members of the excursion were, moreover, at a serious disadvantage in not having any geological map of the districts visited. It was never possible to ascertain, except in à most general way, the areal distribution of any rock, the extent of any intrusion, or the distance to which any metamorphic changes could be traced. In preparing these notes, however, the information obtained in the field has been extended by a careful study of Professor Lacroix's published works, so far as they bear upon the localities in question, and a considerable number of thin sections of the rocks collected from the various occurrences, have also been examined.

In those cases where the granites of the Pyrenees were seen in contact with limestones, as, for instance, in the occurrences about Lac L'Estagnet, Pic du Camp Ras and Cirque d'Arbisson, the limestones near the contact were observed to contain various silicates which had crystallized out in them, as described above. Lacroix considers that in these cases, original differences in the composition of the beds influenced the nature of the minerals developed by metamorphism, but that the material for their growth was largely supplied by emanation from the intrusion. He believes that in the case of bands which were originally pure limestones, the minerals produced are garnet, epidote, zoisite, pyroxenes, amphiboles, quartz, feldspars and axinite. Where the original beds were impure, through the presence of siliceous or argillaceous materials, they are transformed into epidosites, garnet rocks, or feldspathic hornstones. Such limestones with silicates scattered through them, are not, of course, peculiar to the Pyrenees, they are seen in every Archean district in the world where limestones are found. The question always presents itself, as to how far these silicates represent original impurities in the limestone, and how far they are due to exhalations accompanying igneous intrusions. The limestones abutting directly against the igneous mass, even in the Pyrenees occurrences, are often free from these silicates In these contacts, however, the appearances go to show that the limestones

during their recrystallization to marble have had added to them, in certain cases at least, as Lacroix holds, a certain amount of new material, probably from the waters and exhalations accompanying the intrusion; but this infusion of new material seems to be confined to a narrow zone about the contact, and is not by any means a regional phenomenon. In fact, in the occurrences at the Cirque d'Arbisson, some of the limestones of the Cirque itself, while greatly contorted, are practically unaltered in character, still retaining their original blue color and fine texture, and are free from all foreign minerals. The occurrence of axinite about the contacts does not seem to call for any especial notice, seeing that boron exhalations, giving rise to tourmaline, have been recognized as of frequent occurrence in contact zones by all authorities, having been found by Rosenbusch, even in the Barr-Andlau contact zone, which is always cited as affording evidence of the strongest kind, of the absence of metasomatic changes in the rocks about granite intrusions.

As mentioned above, in the district visited on the first two days of the excursion, that is, in the district about Lac l'Estagnet and the Cirque Camp Ras, there is between the altered limestone and the granite a zone, varying greatly in width but usually quite narrow, of what Lacroix terms "Roche Dioritique," and which is considered by him to have been formed by the solution of a portion of the limestone in the granite magma. This rock is said by Lacroix to occur only where the intrusion has limestone as a wall rock. It is a rock generally grayish in color and more basic in appearance than the granite, but of about the same size of grain, varying, however, considerably in grain and character from place to place. Lacroix states that a detailed study of it shows that it is not uniform in composition, but that it varies in minerological composition from a hornblende granite to a basic olivine norite, or even a peridotite. It completely surrounds detached masses of limestone, and has distinctly the appearance in the field of having been produced, as Lacroix believes, by a solution of the limestone along the margin of

the granite. The conditions here are especially favorable for such a process of solution, as the limestone is broken up into a number of disconnected masses, thus exposing a large surface to the action of the granite.

No investigations into the chemical relations of the "Roche Dioritique" have been made, or at least none have been published; its exact chemical composition is unknown. This, however, is a subject on which information is especially required. It is most important to know in how far the composition of the "Roche Dioritique" approaches that of the normal granite of the district, with the addition of varying amounts of lime. It would seem that processes of differentiation must in any case have been at work in the mass after the solution had taken place, for it seems difficult to understand how any addition of lime to a granite magma can produce a peridotite. The only alternative, if this view of the origin of the mass is to be sustained, is to suppose that the exhalations given off by the magma first impregnated the invaded limestone in some places with minerals rich in iron, elsewhere with those rich in magnesia, and having thus produced out of the limestone a series of rocks of very diverse composition, the magma bodily dissolved them and thus obtained that irregularity in composition which caused it to crystallize out as rocks of such diverse composition as the mass cooled down.

The appearance in the field, however, in the opinion of the present writer, supports Lacroix's contention that this narrow band of "Roche Dioritique" was produced by the solution of the limestone in the granite magma about the contact. Detailed chemical studies and an accurate map of the area are, however, required before this contention can be proved, and it seems premature to say, as Lacroix does, "L'évidence de la transformation du granite par dissolution du calcaire est complète."[1] The development of this dioritic contact facies seems, even in the Pyrenees, to be unusual, and its volume as compared with

[1] Le granite des Pyrénées et ses Phénomènes de Contact. Bull des Services de la Carte Geol. de la France; No. 64, p. 60.

that of the granite is insignificant, so that while, even if it be established that dioritic rocks may be produced by the solution of limestone in granite, it would scarcely indicate this as a probable origin for the great intrusions of these rocks met with in various other places.

The other class of granite contacts to be considered are those in which the granite comes against slates, shales, and similar argillaceous strata. In the "Livret Guide" prepared for those taking part in the excursion, Lacroix states that there exist in the Pyrenees, notably in the Haute-Garonne and Hautes-Pyrénées, many granite contacts of the ordinary type, long since described, which present the regular and usual succession of spotted slates, spotted or nodular micaceous schists, and andalusite hornstones; but that the contact zones of the Haute-Ariège, visited on the excursion, were chosen because they present striking examples of a much more intense alteration, in character analogous to certain other French occurrences described by Michel-Lévy, which are characterized by a marked "feldspathisation" of the invaded rocks, indicating the "importance prépondérante" of deep-seated emanations in the case of igneous contacts, and affording evidence of a wholesale incorporation of the invaded rock.

"Au contact immédiat du granite, en effet, s'observe une zone constante dans laquelle les schistes et aussi les quartzites se chargent de feldspaths, soit par imbibition, ces minéraux jouant le même rôle que le quartz dans les schistes micacés, soit par injection en nature du granite lui-même. Il est possible de suivre, pas à pas, tous les stades de feldspathisation et les passages insensibles entre ces schistes feldspathisés (Leptynolites) et le granite lui-même." In certain cases, as in the valley of the Baxouillade (near the Cirque de Ras), he goes on to say, these two types of "feldspathisation" are superimposed in one and the same rock, giving the invaded rock a gneissic facies, which in certain cases is so pronounced that it resembles a veritable gneiss.

This process of "feldspathisation" may thus, according to Lacroix, take place in two ways, (1) by imbibition, and (2) by the injection of little veins of granite all through the invaded rock.

In the first case the shales next to the granite, in what is commonly called the hornstone zone, which contain, as in all contact zones, more or less biotite, have feldspar developed all through them by emanations accompanying the intrusion, being thus converted into micaceous feldspathic schists, called in France Leptynolites. The usual type of Leptynolite is stated to possess exactly the same structure as the non-feldspathic micaceous schists, but under the microscope it is seen to contain grains of feldspar (orthoclase or plagioclase), which, like the quartz grains in the rock, are allotriomorphic, their form being largely determined by the biotite. The proportion of the feldspar present is extremely variable; the mineral may be present merely as a few grains here and there in the rock, or the proportion may be greater —the feldspar in some cases being more abundant than the quartz—as in the case of some of the Leptynolite from near Baxouillade. When this is the case, and the rock becomes coarser in grain with an abundance of mica, it passes into a veritable gneiss.

In the second case the granite is injected at intervals in the form of little veins between the lamellæ of the schist, the veins when followed out to their feather edges fading away insensibly into the schist. This is known as "lit par lit" injection, and also gives rise to a gneiss.

The appearance of the contacts of this class visited on the excursion does not strike the observer as being at all unusual. The explanation which at once suggests itself is that the acid granitic magma which has, by virtue of its acidity, apparently eaten into and dissolved the limestone in certain places and to a limited extent, has not been able to produce any marked effect on the shale. It has forced its way into the shattered strata along the contact, in the usual manner, sending a swarm of little dykes or veins into it in places, and everywhere baking it into a more or less micaceous hornstone-like mass. Fragments of the altered shale, abundant near the contact, less so at some distance, lie scattered about in the granite. These often retain their angular character, but at other times are seen to have been

somewhat softened and pulled out into more or less elongated forms, appearing as dark streaks in the granite. The shale has been recrystallized, as in the case of every hornstone, the phenomenon being, of course, more pronounced in the separated fragments which are completely enveloped in the granite magma. The "lit-par-lit" injection is a not unusual phenomenon of contact in all igneous intrusions, and merely produces a mechanical admixture of granite with shale along the immediate contact of the intrusion without in any way necessarily altering the composition of either rock, or producing anything which is not manifestly a mixture of two distinct rocks. The appearance of feldspar in the altered shale — its "feldspathisation par imbibition" — does not necessarily indicate any addition of material. If there were not alkalies in the shale, the appearance of feldspar in the altered rock would be an evidence of the addition of these elements. But, as the analysis of shales from all parts of the world show, alkalies are almost invariably present, amounting on an average to about 4.75 per cent. This would, in the case of a thoroughly recrystallized rock, afford the material for as much as 25 or 30 per cent. of feldspar, and it would seem that there is seldom more, or in fact as much as this, present in the Leptynolite.

Gneissic rocks of a peculiar type found continually associated with the Laurentian limestones of Canada, and which have precisely the character of the more altered forms of these Leptynolites, when analyzed have been found, in many cases, notwithstanding their content in feldspar, to have a chemical composition identical with that of ordinary roofing slate, being in fact nothing more than shales which are completely recrystallized. On the other hand, thin sections of the most altered leptynolite from Pont de Kerkabanac contain more feldspar than would be expected in an altered shale.

While, then, it is impossible to assert that there has been no addition of material to the altered shale, no evidence seems to have been brought forward that there has been such addition, or that these occurrences differ from the ordinary type of contact

FIG. 1.

Near L'Etang de l'Estagnet.

Ridge of granite in distance. On right, cliff of thinly banded limestone, much altered and filled with garnets.

FIG. 2.

L'Etang de Baxouillade.

In foreground, granite with inclusions of schist and "Roche Dioritique." The mountains in the distance are composed of granite with pre-Cambrian limestone and "Roche Dioritique." The depression in the center of the range is formed by a Permo-Carboniferous limestone, which is altered by the granite.

FIG. 3.
Quarry in Nepheline Syenite—Poussac.

FIG. 4.
Cirque de Gavarnie.

FIG. 5.
Cirque d'Arbisson.

FIG. 6.
Contorted Strata at the Cirque d'Arbisson.

zones. What is required to establish this, is an exhaustive series of chemical analyses of carefully selected material, showing the composition of certain definite beds in their original and altered forms. Such an investigation would be of the greatest interest and highest importance to geological science at the present time.

Although, therefore, it is possible that some of the Archean gneisses which now have no longer the composition of any ordinary sediment, may represent shales which have been transfused with new material by emanations accompanying granitic intrusions, the studies hitherto made of these Pyreneean contacts do not, in the opinion of the writer, afford any conclusive evidence that such emanations have this transforming power. Still further are they from establishing the contention that granitic intrusions are merely great areas of shale or other sedimentary rocks changed in situ into granite, which is the view of their origin held by Michel-Lévy and Lacroix. "Je considère donc toutes ces couches métamorphiques isolées aujourd'hui au millieu du granite comme le résidue non digéré des assises sédimentaires dont le granite á pris la place."[1] "La mise en place du granite s'est effectuée par dissolution graduelle des roches sédimentaires dont il occupe la place."[2] This conclusion would, of course, if established, be of the greatest interest, but the evidence hitherto put forward seems quite insufficient for that purpose.

The metamorphism of the sedimentary strata in the vicinity of the intrusions of the basic rocks (ophite and lherzolite) is also attributed by Lacroix largely to the action of emanations from deep-seated sources. "L'impuissance de la lherzolite à opérer des transformations métamorphiques par l'action de sa propre substance est démontrée par l'absence de zones de passage entre elle et les sédiments métamorphiques et par la nature des minéraux produits à son contact. . . . . La roche modifiée a fourni une partie des éléments nécessaires à la formation des mineraux néogènes, mais beaucoup de ces éléments ont été

[1] LACROIX: Livret, Guide, p. 15.

[2] LACROIX, Le granit des Pyrenées, etc., p. 3.

nécessairement apportés des profondeurs, sous forme d'émanations, ayant une composition chimique différent de celle qu'à priori on pouvait supposer, étant connue la composition de la lherzolite."[1] There is, however, here again the same absence of the chemical evidence which would serve to definitely establish this conclusion.

It is also to be noted that in the Pyrenees, dynamic action has followed the development of the contact zones above described. Lacroix observes that the minerals produced by the contact metamorphism are often much deformed by subsequent movements, but adds: "J'ai pu constater avec précision que les phénomènes de contact jouent un rôle prépondérant dans la production des nombreuses roches métamorphiques que l'on rencontre dans toute l'étendue de la chaîne."[2] As, however, it is a matter of extreme difficulty, if not an impossibility, in all cases to determine to which class of metamorphic agencies certain rocks are due, the question as to how far dynamic action may have at least contributed to some of the changes attributed to contact action is one which cannot be considered as entirely settled.

To sum up therefore it may be said, that while the transfusion of a certain amount of material into the limestones along the immediate contact of the intrusions and also a solution of the limestone to a limited extent in certain cases seems highly probable; the wholesale transformation of limestone into diorite, or of shale into gneiss and granite, which has been described in the case of these contact zones of the Pyrenees, is as yet very far, indeed, from being proved.

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[1] LIVRET, Guide, p. 5.

[2] Les Phénomènes de contact de la Lherzolite et de quelques Ophites des Pyrénées. Bull. des Sciences de la Carte Géol. de la France, No. 42, p. 133.

VALLEYS OF SOLUTION IN NORTHERN ARKANSAS

PROFESSOR G. F. MARBUT has called attention to valleys of solution in Missouri.[1] Before this had come to the present writer's notice, he had become convinced that a type of valley which occurs in large numbers in the Boone chert of Arkansas owes its existence to the differential solution of the rock.

The Boone chert lies at the base of the Mississippian series in Arkansas. Over a large part of the region north of the Boston Mountains, erosion has left this as the surface rock. It approximates 400 feet in thickness and is essentially an immense deposit of limestone containing chert which varies greatly in amount, both horizontally and vertically.[2]

In all places where the Boone chert is the surface rock, the calcareous portion has been partly removed by solution, leaving a residue of chert, in places several inches deep, on the surface. The universal distribution of the small chert particles over the surface reduces the run-off to the minimum and increases the underground water to the maximum. As a consequence, valleys of solution are numerous throughout the region in which this is the surface rock. So different are these valleys from those of corrasion that they attract the attention of even the untrained observer. While seldom of great length, their length is always great in proportion to the width, and the latter is strikingly uniform throughout. To borrow a term from biology, they are always bilaterally symmetrical, and their slopes are steep (Fig. 1). They are remarkably straight, seldom deviating from a straight line more than a few feet except at the points where two valleys unite (Fig. 2). Probably the most striking feature about them is that they head suddenly, the heads often having exactly the appearance of half a sink-hole cut with a vertical

[1] Missouri Geological Survey, Vol. X, pp. 88–92.

[2] For a full description of the Boone chert, see Rep. of the Ark. Geol. Surv., 1890, Vol. IV., pp. 94–107.

plane through the center. Not infrequently the heads are forked, as shown in Fig. 1. The bottoms and slopes are covered with angular residual chert, leaves and branches of trees (Fig. 1). If surface water ever flows through the upper parts of these valleys, it is only after excessive rainfalls. Extended travel over the region has not yet brought to the writer's notice a single case in which the upper part of one of these valleys has been occupied

FIG. 1.

by surface water in sufficient quantity to remove the residual chert.

Unlike the valleys which Professor Marbut describes in Missouri, these valleys are narrow and steep-sloped in their upper parts and pass into rather wide, open valleys which owe their forms to both solution and corrasion. The topographic transition from that part of the valley that is due wholly to solution to the part that is due to both solution and corrasion is of course gradual. The point, as the writer conceives it, where the one passes into the other is determined by the groundwater level. Above the point where the valley cuts into the groundwater, the work is done by solution; below that point a surface stream

exists which adds the work of corrasion to that of solution, the latter occurring mainly on the valley slopes above the stream bed. As this work goes on and the stream bed continues to be reduced more and more below the average level of groundwater,

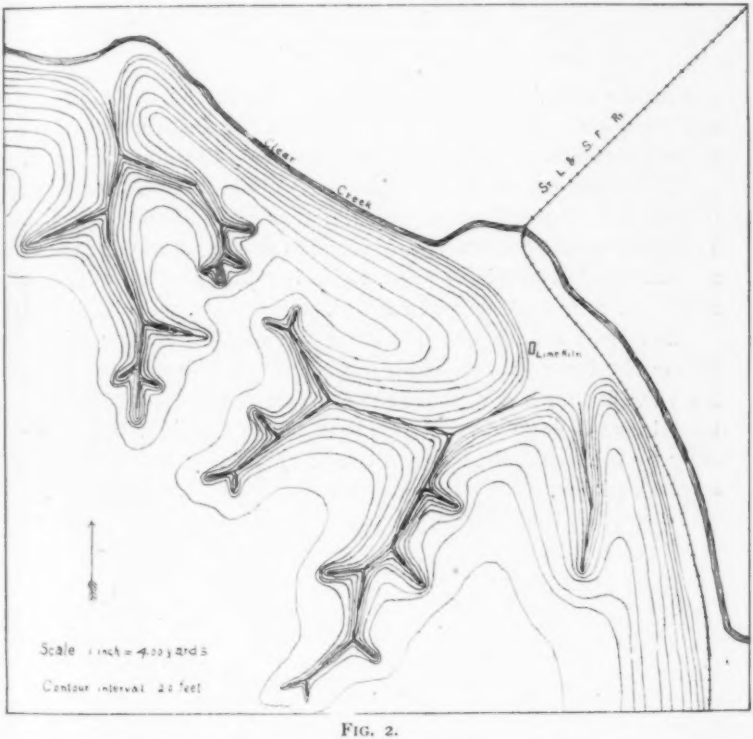

FIG. 2.

the stream grows in size, and in time, by meandering, is able to produce a wide valley.

The point at which the valley cuts into groundwater of course varies with the seasons, but on the whole it is moving up the valley because of the differential solution brought about by the large amount of groundwater moving down the slope from either side and meeting beneath the bed of the valley.

Fig. 2 is a map of two of these valleys with their tributaries, four and a half miles north of Fayetteville. The map was made with a plane-table without correction for magnetic variation. These are typical of valleys that occur in the Boone chert of Arkansas by the thousand. The heavy lines are placed along the bottoms of the valleys only to bring to notice the angles at which they join each other. These angles vary from 60 to 100 degrees or more, the most common one being 80 degrees. It will be noticed that the angles at which the main valleys and their tributaries unite are quite different from those of corrasion.

The writer thinks there can be no doubt but these valleys are determined by the jointing of the horizontal beds of rocks. The double heads which are so common among them are tributary valleys in their incipiency, following joints which intersect along the course of the main valley.

The large valleys which contain the master streams of the Boone chert region were probably inherited, with their streams, from the former superimposed rocks, but the valleys here mentioned owe their origin and development to solution, aided possibly by the removal of part of the residual chert after the most excessive rains.

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STUDIES FOR STUDENTS

THE STRUCTURE OF METEORITES. I.

THOSE portions of cosmic matter which from time to time fall to the earth and which are known under the general name of meteorites, have now for about a century been objects of collection and study. Earlier studies of this matter were, on account of its limited quantity and variety, necessarily confined chiefly to the description of individual masses. Comparative study, has, therefore, been carried on to only a small extent and the possible knowledge to be gained by investigation along this line is as yet far from complete. The number of localities from which meteorites are now known may be stated in round numbers as 550 and the total weight of cosmic matter now preserved and in one way or another available for study, as about 161 tons (146,716 kilograms).

Lines of investigation.—The lines along which the study of meteorites has been and is being conducted can be classified as follows, each, of course, being more or less intimately related to or inclusive of the other: (*a*) chemical, (*b*) mineralogical, (*c*) petrological, (*d*) physical, and (*e*) structural. Each of these may be (1) analytical, and (2) synthetical, and may include (3) the study of terrestrial analogies. Of the above courses of investigation the first three have been the lines along which study has been most extensively conducted hitherto. Summarizing briefly their results, it may be stated that the chemical investigation of meteorites has resulted in the identification of twenty-five elements, all similar to those known upon the earth; the mineralogical in the determination of at least twenty mineral species, some of which are similar and others dissimilar to terrestrial compounds, and the petrological in the classification and tabulation of the characters which meteorites display as mineral aggregates.

The physical investigation of meteorites has been confined chiefly to studies of their spectra and comparisons of these with the spectra of comets, nebulæ, and other heavenly bodies. Studies of thermo-luminescence, magnetism and polarity as exhibited by meteorites have also been made. With the results of the structural studies of meteorites it is the purpose of the present paper to deal in some detail.

Structure a feature distinguishing meteorites from terrestrial rocks.—It is from the point of view of structure that meteorites differ most completely from terrestrial rocks. In chemical, mineralogical, petrological and physical characters some meteorites closely resemble terrestrial rocks. The meteorite of Juvinas, for instance, so far as the above characters are concerned, is similar to a basalt, while many of the iron meteorites find a perfect analogue in the terrestrial irons of Greenland. When the structure of meteorites is considered, however, a distinction is apparent. No resemblance to the clastic texture of the Juvinas meteorite is to be found among terrestrial basalts, nor does the terrestrial nickel-iron show satisfactorily the Widmanstätten figures so characteristic of the iron meteorites.

It is along this line of study that the geologist finds problems which his science is especially adapted to solve, for the problems afforded are similar in many respects to those included under the group of structural and dynamical, or, as it is sometimes termed, phenomenal geology. Just as studies of the latter sort avail to give a knowledge of the forces and conditions under which different rock structures and rock movements are produced, so studies of the structure of meteorites may be expected to discover the conditions under which cosmic matter is formed and the forces to whose action it is subject in space. Since, further, this cosmic matter reaching us as meteorites has striking and important analogies with that, not alone of the crust of the earth, but it may be believed also of its entire substance, the fascinating possibility is presented of reading in the mass of meteorites many chapters in the history of the earth which would otherwise be locked up within its interior.

Matter of meteorites of two kinds. — Matter constituting meteorites may be described as of two kinds, metallic and stony. The metallic matter is chiefly an alloy of iron and nickel, the stony matter chiefly the silicates chrysolite, pyroxene, and feldspar. Single meteoric masses may consist of but one of these kinds of matter or may be made up of a union of the two.

Three groups of meteorites according to their components. — According to the relative quantities of each of the two above mentioned kinds of matter it is convenient to divide all meteorites into three great groups. Those made up wholly or largely of metal (*aerosiderites*, *holosiderites*) form the first group. Those made up of about equal quantities of metal and stone (*aerosiderolites*, *lithosiderites*, *syssiderites*) form the second group. Those made up wholly or largely of stone (*aerolites*, *sporadosiderites*) form the third group. No sharp dividing line can be drawn between these groups. They pass into one another by every gradation, and meteorites of the two kinds even occur in the same fall. Yet meteorites of these groups differ in many essential characters and their separation becomes a matter of great convenience in study. For purposes of the present study the three classes will be sufficiently designated by the terms iron meteorites, iron-stone meteorites, and stone meteorites.

Two groups of meteorites according to their origin. — With respect to their origin meteorites may be either (1) monogenic (of single origin) or (2) polygenic (of various origin). Most of the iron meteorites are plainly monogenic. Many show such homogeneity and uniformity of structure as could belong only to a single crystal. Thus the iron meteorite of La Caille, a mass of 591 kilos in weight, contains inclusions of troilite arranged in parallel rows throughout in such a manner as to indicate a uniform and continuous crystallization of the entire mass. Likewise from a mass of a Toluca meteorite a cube may be cut which shows on etching a perfectly regular octahedral structure throughout. The same parallelism of planes may be traced on an etched section of almost any of the so-called cubic meteorites, such as Coahuila, Hex River, etc. A few iron meteorites

are however plainly polygenic. An etched section of the Mt. Joy meteorite for example shows the mass plainly to be made up of irregular iron fragments. The structure of each fragment as shown by its etching figures is *sui generis*, and indicates an independent origin. The iron of Zacatecas is likewise made up of individual grains the size of a hazelnut to that of a walnut. These are separated by areas of troilite.

Many of the iron-stone and stone meteorites are monogenic but more are made up of two or more different kinds of rock. To draw the dividing line between the monogenic and polygenic meteorites of the last two classes is not an easy task and the opinion of no two observers would probably be the same in regard to it. The meteorite of Stannern for instance was described by one observer as crystalline and by another as clastic. Tschermak, who has given the matter profound study, is disposed to regard practically all stone meteorites as of a tuffaceous or clastic character while Wadsworth after examining many meteorites concluded that none which he had examined could be considered "fragmental in the sense of consolidated cold masses joined together." The present writer can only state that in his opinion some stone meteorites are so uniform in character that crystallization from a single magma is indicated while on the other hand many meteorites have a clearly brecciated and tuffaceous character showing them to be polygenic.

Structures of terrestrial origin to be eliminated.—In all study of the structure of meteorites with a view to learning their preterrestrial history, care should be taken to eliminate all phenomena of terrestrial origin. Thus the crust of meteorites and their surface markings are usually considered, and without doubt properly, to be produced during the passage of the mass through the earth's atmosphere. The possible effects on the interior of a meteoric mass, of heat developed by such passage should also be borne in mind in study. Again the force of impact with which a meteorite strikes the earth is often very great. It should be considered whether such a blow might not give rise to phenomena of internal movement within the mass. Again

processes of corrosion and decomposition go on if the meteorite is exposed on the earth's surface for any length of time, which may have their effect on the structure of the meteorite. These therefore must be judged and eliminated. Again, the fissures found in meteorites are believed by many to be the result of cracking from the sudden development of heat caused by the entry of the mass into the earth's atmosphere and the veins of meteorites are by some thought to be fissures filled by matter fused by such heating. Due weight must be given these possible effects and all that are certainly of terrestrial origin must be left out of consideration.

Uniformity of mass structure of single meteorites.—The iron meteorites usually show remarkable uniformity of structure throughout. Sections from different portions of a single mass or even different masses of the same fall usually give on etching, figures so similar that the meteorite to which they belonged can be recognized at a glance, even if the specimens have been widely separated. In some, however, there are variations in the same mass. Thus the Floyd county iron according to Kunz and Weinschenk while possessing a generally cubic structure shows portions which are granular; the Linnville iron according to Kunz is partly of cubic structure and partly amorphous. The Carlton iron is partly rich in plessite and partly poor in plessite. The Holland Store iron has portions coarse-grained and fine grained. Four of the five masses found near Staunton, Virginia, are quite similar in structure, showing on etching, figures made up of short, swollen bands. The etching figures of the fifth mass are, however, made up of long, straight bands. Moreover the taenite of the first four is brittle, of the fifth elastic. So sharply does the latter mass differ from the others that Brezina regards it as belonging to a different fall, but it is more likely that the differences are those of structure. Such exceptions are however so rare as to emphasize the fact that on the whole iron meteorites are uniform in structure. Speaking in a general way the iron-stone and stone meteorites are likewise uniform in mass characters although such as are

clastic or brecciated have the variations which might be expected from the accidents of aggregation. The monogenic meteorites may show variations from fine grain to coarse grain and vice versa and some portions may contain more stone or metal than others, but the general structure may be said to be uniform.

Similarities of structure in meteorites of different falls.—While the individuals of a single fall are usually similar in structure and composition those of different falls often differ so that they may be easily distinguished. In comparing the meteorites of a large number of falls, however, similarities are readily seen which permit the grouping of several falls together as being of practically identical matter. A number of classifications of this sort have been made of which those of Brezina and Meunier are the latest and most complete. Brezina, who makes structure the leading feature of his classification, has thus reduced all known meteorites to sixty-one groups, while Meunier, with whom mineralogical composition is the chief criterion, makes sixty-two groups.

Degrees of coherence.—The iron meteorites are, as might be expected, usually strongly coherent and tenacious to a high degree of malleability. Yet there are variations in this respect. The iron meteorites showing coarse etching figures can usually be sawed only slowly and with great difficulty, while those of an amorphous or finely crystalline character cut more readily. Some iron meteorites, such as those of Coahuila and Nelson county, can be broken readily by the blow of a hammer. Among the stony meteorites all stages of consolidation may be traced from those of an almost flint-like toughness (Long Island) to those so friable as to crumble on handling (Warrenton). The majority of stony meteorites are fairly coherent so as to take a good polish.

Kinds of structure according to texture.— According to what is often known as rock texture, meteorites display a number of variations which are for the most part entirely comparable with similar variations seen in terrestrial rocks and may be described by the same terms. Accordingly, among the monogenic meteorites

crystalline, cryptocrystalline and vitreous or amorphous structures may be noted. Among the polygenic meteorites, brecciated, agglomerated, psammitic or sandstone-like and tuffaceous structures may be noted. Stratified, foliated, and fibrous structures are entirely lacking. Both among monogenic and polygenic meteorites occurs a kind of structure resulting from the mass

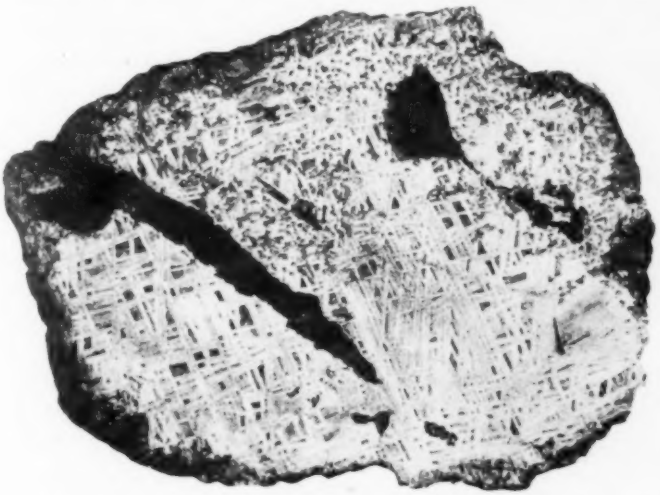

FIG. 1.—Widmanstätten figures. Meteorite from Toluco, Mexico.

being made up largely of little spheres called chondri. The structure of such meteorites is not strictly comparable to that found in any terrestrial rocks. Meunier describes it by the term oölitic, but the analogy is not a very close one. The structure, therefore, requires a distinctive term, chondritic, meaning a rock made up wholly or largely of chondri.

CRYSTALLINE STRUCTURE.

Iron meteorites.—Sections of most iron meteorites when heated or etched by acids or other etching agent display upon their surface well-marked figures formed of series of parallel bands intersecting in two or more directions. These figures

are called, after Alois von Widmanstätten, who first produced them in the year 1808 by heating a section of the Agram meteorite, Widmanstätten figures. The production of these figures is evidence that the meteorites on which they occur (1) have a well-defined crystalline structure and (2) are not homogeneous in composition. Evidence of crystalline structure is not confined to results obtained by etching: many meteorites show in their natural condition a structure of plates intersecting at definite angles. Study of the angles at which the bands meet both in etched and natural specimens shows that the crystallization of most iron meteorites is octahedral, *i. e.*, they are formed of plates or lamellæ arranged parallel to the four pairs of faces of the octahedron.

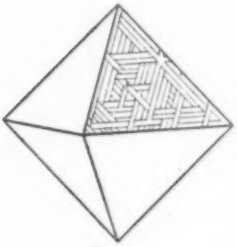

FIG. 2.

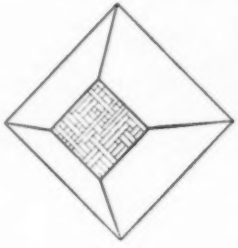

FIG. 3.

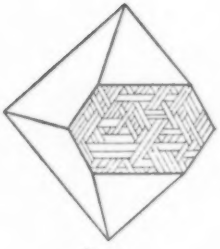

FIG. 4

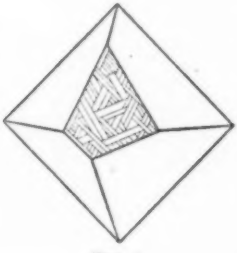

FIG. 5.

Though this arrangement may for practical purposes be considered a simple one, it is really according to Linck the result of a polysynthetic twinning. The angles at which the bands intersect in any given section depend wholly on the direction of the section, as the accompanying figures will show. If the section is parallel to an octahedral face it will show three systems of bands intersecting at angles of 60° (Fig. 2). If the section is parallel to the face of a cube there will be two systems of bands intersecting at angles of 90° (Fig. 3). If the section is parallel

to a dodecahedral face there will be two systems of bands intersecting at angles of 109° 28′ and two others parallel to each other which will bisect this angle (Fig. 4). Sections in any other direction (obviously by far the most common) will produce bands running in four directions and intersecting at unequal angles (Fig. 5). A small number of iron meteorites show a cubic rather than an octahedral crystallization, *i. e.*, they are formed of plates arranged parallel to the faces of a cube. These are known as "cubic irons," or hexahedrites. A still smaller number exhibit no crystalline structure nor Widmanstätten figures. These are known as amorphous irons or ataxites. The relative numbers of these kinds of irons given in Brezina's classification are, of the octahedral irons, 125; of the cubic irons, 26; and of the ataxites, 14. Among the octahedral irons the particular figures exhibited will vary slightly with almost every fall, on account of varying width, length, shape and arrangement of the bands and abundance and forms of included matter. Width of bands is made by Brezina the basis of classification of the octahedral irons. He describes the widths as varying from more than 2.5 ^{mm} to less than 0.1 ^{mm}. When the intimate structure of the bands themselves is considered, they will be found to consist of a broad band of dull luster and iron gray color depressed below the surface when etched or covered with a thick layer of oxide when heated, bounded on either side by thin lamellæ of bright luster and silver white to yellow color, which stand out in relief or are little oxidized. To the broadly banded alloy, Reichenbach, who first investigated this structure, gave the name of Balkeneisen or *kamacite*, from *κάμαξ*, a pole or shaft. To the narrow banded alloy he gave the name of Bandeisen or *taenite*, from *ταινία*, a fillet or ribbon. When angular interstices occur between the intersecting bands they are often filled with an alloy intermediate in properties between kamacite and taenite. To this Reichenbach gave the name of Fulleisen or *plessite*. The three alloys together he called "the triad." Chemical analysis of the members of the triad shows them to be alloys of nickel and iron, the first two of which have a fairly

uniform chemical composition, though not sufficiently constant to warrant their being considered distinct mineral species. The percentage of nickel is lowest in kamacite, thus accounting for its greater solubility in acid. The formula $Fe_{14}Ni$ expresses the usual proportion of iron and nickel which it contains. Taenite contains a much larger proportion of nickel and hence is less soluble in acid. Its formula has been given both as Fe_6Ni and Fe_5Ni_2. According to Tschermak the taenite of the Ilimäe meteorite consists of a network of different substances, and it is doubtful whether in any meteorite it is a homogeneous substance. The third member of the triad, plessite, has a very variable composition and the latest investigations make it doubtful whether it differs essentially from kamacite. Inclusions of other minerals occurring in iron meteorites are usually surrounded by a layer of kamacite. Kamacite of this sort, while it does not differ in composition or structure from the ordinary kamacite, has been designated by Brezina as "*wickel-kamazit*" (swathing kamacite) and was called by Reichenbach "Hulleisen." While the octahedral irons always contain two or more of the above alloys, cubic irons contain only one, viz., kamacite. This usually shows a parallel banded structure on etching, but is not divided into well-marked lamellæ. Etched sections of cubic irons also exhibit fine depressed lines called Neumann lines. They are somewhat promiscuously scattered, having neither the abundance nor the regularity of Widmanstätten figures. They are usually interpreted as intercalated lamellæ in twinning relation to the main individual which are more easily dissolved by acid than the other lamellæ. They have been likened to the twinning lamellæ parallel to $-\frac{1}{2}R$ often seen on a piece of calcite. Tschermak regards their formation as simultaneous with the crystallization of the iron, while Sadebeck and Linck consider them of secondary origin, perhaps as a result of jar or shock. Many cubic irons also exhibit orientated sheen (*krystal damast, moiré metallique*). This is formed partly by differential etching

of parallel bands and partly also by the above described Neumann lines. Sheen, Neumann lines, and parallel banded structure of the cubic meteorites will be found on close examination to characterize the kamacite of many octahedral irons (*schraffirten kamazit* of Reichenbach), while the kamacite of other octahedral irons is wholly granular (*fleckig kamazit* of Brezina).

Regarding the part played by the different alloys in the process of crystallization, opinions differ, though the general opinion is that the kamacite crystallized first and the other substances arranged themselves accordingly. Sorby likened the process to the forming of needles of ice on the surface of water, leaving angular spaces which were filled later. J. Lawrence Smith on the other hand, thought that the foreign minerals, such as schreibersite, separated and crystallized first and the purer alloys followed. Huntington is of a similar opinion and draws attention to the close resemblance in appearance between Widmanstätten figures and the arrangement of inclusions of magnetite in mica in support of the view.

Most authorities agree that the crystalline structure exhibited indicates that the masses must have remained for a long time in a fused or viscous state from which they cooled but slowly. The conclusion of Tschermak was that "the greater number of meteoric irons exhibit a structure which indicates that each formed a part of a large mass possessing similar crystalline characters and the formation of such large masses presupposes long intervals of time for tranquil crystallization at a uniform temperature." Sorby reached a similar conclusion and regards the Widmanstätten figures "as the result of such a complete separation of the constituents and perfect crystallization as can occur only when the process takes place slowly and gradually. They appear to me to show that the mass was kept for a long time at a heat just below the point of fusion."

2. *Iron-stone meteorites.*—The metallic portions of most meteorites of this class show Widmanstätten figures on etching. The mineral silicates entering into the composition of the mass also often exhibit well-defined crystal forms, the perfection of which is

sufficient to permit accurate measurements of the crystal planes. A curious feature of these crystals, however, and one which has as yet received no adequate explanation is that they usually exhibit a rounding of the solid angles and edges, giving an appearance of a sphere on which facets have been cut.

3. *Stone meteorites.*—To what extent a primary crystalline structure characterizes stone meteorites, is a point regarding which, as has been said, no two observers are likely to agree. The minerals of many meteorites occur in well crystallized form, but whether they have crystallized *in situ* or are mere splinters from previously existing masses is a disputed point in most cases. The number of stone meteorites showing a holo-crystalline structure similar to that characterizing terrestrial rocks is certainly small. Such as may be of this character are fine-grained and resemble fine-grained basalts in their structure.

Among minerals occurring in well defined crystal forms, whatever their relation to the mass as a whole, enstatite, chrysolite, augite, and plagioclase are the most common and characteristic. The crystals of these minerals usually have well-defined boundaries and exhibit planes corresponding to those of terrestrial minerals of the same kinds. Twinned individuals are common and a lamellar arrangement of inclusions is sometimes seen. There is a complete absence, however, of layers of growth or of zonal structure so common in the minerals of volcanic terrestrial rocks. The crystal individuals often contain large quantities of glass and often present a highly fissile structure. Another remarkable feature is a complete absence of fluid inclusions. Gas pores while occasionally to be seen are exceedingly rare. The latter fact, it may be remarked, furnishes a strong argument against any theory which regards meteorites as having been formed directly from vapors.

CRYPTOCRYSTALLINE AND AMORPHOUS STRUCTURES

1. *Iron meteorites.*—The term amorphous irons or ataxites is usually used to designate iron meteorites which give no Widmanstätten figures on etching. Such irons are few in number and the

present supposed number will doubtless be further reduced by careful study since some accredited meteorites will be found to be artificial irons and others will give Widmanstätten figures on further treatment. The true ataxites resemble ordinary cast iron in structure. There are sometimes variations in a single mass from a compact homogeneous structure to one of a coarse grained character. Several show indistinct broad bands and others a sheen (*Eisenmohr, moiré metallique*) on etching. Inclusions of graphite, phosphides and sulphides of iron (such as schreibersite, troilite, etc.) occur as in the octahedral irons. Unusually high content of nickel characterizes some, while others have an average composition. On the whole the ataxites may be said to form an anomalous and little understood group.

2. *Stone meteorites.*—No stone meteorites are amorphous in structure as a whole; only the ground mass is sometimes found to be of this character. In some cases a ground mass appearing amorphous is found in reality to be made up of consolidated fragments of dust-like minuteness. In other cases, as in the stones of Richmond and Goalpara, the ground mass is really semi-glassy and unindividualized. The ground mass of most of the carbonaceous meteorites is of a black unindividualized character, and appears closely allied to the substance to be described later as forming veins. In the brecciated stones of Orvinio and Chantonnay a black ground mass cements the fragments of chondritic texture together and exhibits a distinct flow structure about them. A brown glass is also found cementing together some of the crystalline and tuffaceous meteorites.

BRECCIATED STRUCTURE.

This is of rather common occurrence. According to Wülfing's classification it characterizes meteorites of sixty-two falls. Breccias occur both of the type of angular fragments compressed together and of angular fragments imbedded in a ground mass which may have been at one time in a fused or pasty condition. Among the iron meteorites the fragments are largest in the Mt. Joy meteorite. The contour of each of these is so distinct that

there can be little doubt that the mass was made up by the aggregation of solid angular fragments. The meteorites of Zacatecas and Kendall counties have a similar structure, though the component fragments are much smaller.

Some of the iron-stone meteorites have likewise a brecciated structure resulting from the imbedding of angular masses of silicates in a metallic base. The meteorite of Copiapo, for example,

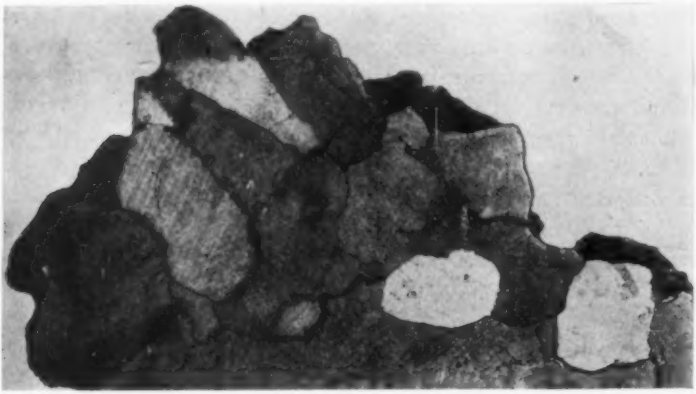

FIG. 6.—Brecciated structure. Mt. Joy Meteorite.

has such a structure and its formation is exactly analogous, in the view of Meunier, to the dike breccias produced on the earth by intrusive igneous eruptions tearing off fragments of the rock through which they have ascended and enclosing them in its pasty mass. In this case the intrusive matter was fused nickel-iron. In other iron-stone meteorites, such as Vaca Muerta and Eagle Station, the silicate fragments are likewise angular. Reichenbach is authority for the statement that the iron in these adapts itself to the form of the stone rather than the contrary.

The fragments forming the breccia in stone meteorites are often of considerable size. The largest which I have noted in the stony meteorites (Weston) is about one cubic inch in contents.

Often the fragments differ enough in color from one another, or from the ground mass, so that the brecciated character is plainly visible to the naked eye. In the stone of Weston, for example, the ground mass is gray, the enclosed fragments blue. In the stone of Siena the angular fragments are of a dark color and the enclosing magma is light colored, while of Bandong, Saint-Mesmin and others the reverse is true. In other meteorites the two components differ chiefly in grain and coherence, as in the meteorites of Jelica, Manbhoom, and Soko-Banja. In these the ground mass is of a somewhat coarse, friable character, while the enclosed fragments are of a dark, fine-grained rock. In regard to the ground mass of other brecciated stone meteorites it may be stated that it may itself be made up of rock splinters, *i. e.*, have a tuffaceous character, or it may be crystalline or half glassy. The half glassy ground mass of the Orvinio and Chantonnay meteorites, as already noted, shows a distinct flow structure around the fragments which it encloses.

AGGLOMERATED, SANDSTONE-LIKE AND TUFFACEOUS STRUCTURES.

These may be said to differ from brecciated structure only in the smaller size of the component fragments. The fragments may range from the size of small peas in meteorites of agglomerated structure through that of coarse sand in those which are sandstone-like to that of splinters and fine dust in the tuffaceous meteorites. In the agglomerated meteorites it is often possible to recognize different kinds of rocks. Thus in the Parnallee meteorite Meunier believes he has recognized seven distinct lithologic types. Of the sandstone-like meteorites that of Chassigny is the best example. It is made up of rounded grains of the size of coarse sand. The Shergotty and Ibbenbühren meteorites are likewise granular in appearance. Not all observers, however, agree that the above are clastic in their origin. The tuffaceous structure is a common one in meteorites, Tschermak, as already noted, regarding practically all stony meteorites as of this nature. The resemblance of these to terrestrial volcanic tuffs is very close, though the stratification which usually characterizes the latter has never been

observed. The tuffaceous meteorites are made up of splinters and dust varying in degree of consolidation. They are often finely porous so as to soak up fluids readily. The splinters of which they are made up may be similar in character (Shalka) or strikingly dissimilar (Luotolaks).

O. C. FARRINGTON.

(To be continued)

EDITORIAL

THE thirteenth meeting of the Geological Society of America, held in Albany, N. Y., was very satisfactory. The location was sufficiently central to insure a good attendance, the hotel accommodations were excellent and convenient to the place of meeting, and the number of papers was not more than could be read and discussed within the time of the meeting. The local committee, Dr. F. J. H. Merrill and Dr. J. M. Clarke, are to be congratulated on their hospitality and the success of their arrangements.

The postponement of President Dawson's address to the last day of the meeting was regretted by those who were unable to remain through the three days. It would seem advisable to have the presidential address delivered on the second day of the meeting, when there is the greatest number of members present.

The most notable feature of this meeting of the Geological Society, in the city that is looked upon as the cradle of American geology, was the conspicuous absence of a suitable monument to the memory of those pioneers of geological science who have opened a highway to stratigraphy through New York state, and have made of the state a corner stone of the geological structure of the whole country. Such a monument should take the form of a building in which not only the names and records of New York's venerated geologists may be inscribed and their collections preserved, but where their labors may be carried forward and from which inspiration and assistance may spread to geological workers throughout the state. In a state less than New York the absence of such a monument might pass unnoticed.

J. P. I.

THE second annual meeting of the Cordilleran section of the Geological Society of America was held on December 28 and 29. The morning session on the 28th took place in the council room of the California Academy of Sciences, in San Francisco. For the succeeding three sessions the members gathered in the rooms of the Geological Department of the University of California.

The following persons were present at the meeting of the section:

W. P. Blake, E. W. Claypole, A. S. Eakle, H. W. Fairbanks, E. W. Hilgard, W. C. Knight, A. C. Lawson, H. W. Turner, F. M. Anderson, W. C. Blasdale, F. C. Calkins, H. W. Furlong, O. H. Hershey, G. D. Louderback, C. F. Newcombe, W. J. Sinclair, J. C. Merriam.

At the first session Professor Wilbur C. Knight was elected chairman, Professor Andrew C. Lawson, secretary, and Dr. A. S. Eakle, councilor for the ensuing year.

In the course of the four sessions the following papers were read and discussed:

The Evidences of Shallow Seas in Paleozoic Time in Southern Arizona. By W. P. BLAKE, Tucson, Ariz.

In the mountain ranges of southern Arizona there is abundant evidence of shallow seas and shore lines in Paleozoic time. These shores were not, perhaps, a continental margin, but rather the borders of islands, crests of submerged mountain ranges rising at intervals above the Paleozoic ocean and with a trend or direction corresponding eventually to the direction of the mountain ranges of the region.

A cross-section of the territory northeasterly from the Gulf of California shows a succession of mountain ranges, some fifteen in number, in most of which ancient sandstones and conglomerates of Paleozoic age have been identified. Many of the exposures of quartzite are very thick, and these quartzites generally rest upon a coarse-grained porphyritic granite. Deep-sea deposits are not wanting. Thick beds of limestone, especially those of the Carboniferous, give evidence of depressed areas and of oscillations of level. So, also, the existence of thick, uplifted beds of graphitic coal in the Chiricahua Mountains bear testimony to the former existence of land areas, and show a far western extension of the vegetation of the Carboniferous.

Two localities of Devonian beds were described; one in the Santa Ritas and another at the northern end of the Santa Catalina Mountains.

The probable existence of Cambrian beds at several places was pointed out and the ancient tabular gneissic rocks of the Catalinas were referred to the Archean, and regarded as probable equivalents of the Huronian and Laurentian.

The Sierra Madre near Pasadena. By E. W. CLAYPOLE, Pasadena, Cal.

The paper opened with an expression of the surprise with which geologists who have worked principally in the East witness the enormous development and the excessive diastrophism exhibited by Tertiary and even by very late Tertiary strata in the West, and these characters are as well seen in California as in any other western state. The whole Tertiary period has apparently been signalized by thick accumulation, with alternate elevation and depression. Not less has its passage been characterized by volcanic outbursts of intense energy and by quiet outflows of lava almost unequaled in massiveness and extent.

Two great mountain ranges diverging in the north and meeting again in Kern county, inclose between them the San Joaquin Valley. This southern meeting forms one of the great natural features of the state—the Tehachapi Divide.

Speaking now only for the southern part of the state, there seems ample ground for the belief that these ranges have existed from at least Cretaceous if not from earlier Mesozoic time. It is not otherwise easy to find a source for the enormous Pliocene, Miocene and Eocene accumulations of the Pacific margin so far from the Sierra Nevada.

Thick gneissic strata of two types, and standing nearly vertical, compose the range of the Sierra Madre near Pasadena. That to the south contains a large proportion of hornblende, weathers rapidly and deeply, and is consequently eroded with comparative facility. That to the north is largely feldspathic, contains little hornblende, and of it consist the white crags that stand out so boldly on the upper slopes. The former of these masses cannot be less than 2000–3000 feet thick, but it does not rise in the mountain to a greater height than 3500 feet.

Of the wreckage from these two gneissic masses the material filling the valley of Pasadena is composed. From great bowlders near the

foot of the Sierra it gradually diminishes till it becomes, in many places, a fine gravel and at last a fine silt. This last composes the adobe land around Los Angeles and also the many sheets of the same material which lie in the gravel, and are the holding-ground of the water supply. This has been so largely exploited during the two late dry seasons that the work has resulted in restoring confidence in the water resources of the valley, of which some had become rather doubtful.

The highly aluminous nature of many of these beds indicates a very extensive decay or kaolinization of the gneisses of the Sierra and together with the diluvial arrangement of the Pleistocene wash in the valley rather indicates a long continuance of the present climatic conditions than a past of greater and steadier rainfall.

The multiplication of wells has not yet shown any effect in lowering the water level unless perhaps in a few cases and this result is the more surprising and gratifying because it comes after two dry seasons in which only eleven inches of rain have fallen. Already this year, a greater total has been received than the above though the wet period has scarcely begun.

When to this is added the storage of the rainwater in tanks and ponds and the reforesting of the Sierras, wherever possible, it will be seen that the maintenance of the water supply in the future is encouraging.

Bates' Hole. By WILBUR C. KNIGHT, Laramie, Wyo.

Bates' Hole, a great natural depression, is located along the east and west boundary line between Carbon and Natrona counties, Wyoming; extending southward from six to ten miles into Carbon county and from twenty to twenty-five miles into Natrona county. The bottom of this depression is 800 feet below the rim near the head and over 1700 feet below it near the Platt River. The drainage is practically confined to Camp Creek which rises at the southern end of the Hole; but which affords water for only a portion of the year, and Bates Creek which rises in the Laramie Mountains and furnishes quite a stream. The country about this area is comparatively level; but to the eastward only a few miles rise the Laramie Mountains, and to the westward the Indian Grove and other ranges, which are made up of Mesozoic, Paleozoic, and Archean rocks. In length Bates' Hole varies from twenty-five to thirty-five miles and in width from six to twelve miles;

the lower end being much the wider. The dominant formation entering into the structure of this region is Tertiary; but this rests nearly horizontally upon a very uneven floor of older rocks, which in the central portion have been exposed and suffered extensive erosion. From the rim the slopes are very steep throughout, seldom being less than 15° to 20° and usually much higher and in many instances from 28° to 34°. Occasionally there are vertical walls of the Tertiary rocks from 100 to 200 feet, carved in the most unusual manner and often cut with deep, narrow, dry gorges. Capping the highest Tertiary escarpments there is a heavy conglomerate of unknown age; beneath this are the Titanotherium beds which have a thickness of about 600 feet, and in local depressions in the Cretaceous series underlying this region there is a third series of Tertiary beds, composed of variegated clays and sands that is in all probability Eocene. Along the Platte River all of the Tertiary rocks have been removed and along the Laramie Mountains there are exposed in natural order, Cretaceous, Jurassic, Triassic, Carboniferous, Cambrian, and Archean as one ascends the range. Along the Tertiary escarpments are numerous stunted pines (*Pinus flexlis*) whose roots are exposed from one to eight feet which signifies very rapid erosion. This erosion has been very general and data that will aid us in determining the age of Bates' Hole are well in hand. Illustrated with lantern slides.

A Geological Section through the John Day Basin. By JOHN C. MERRIAM, Berkeley, Cal.

The John Day River and its tributaries have exposed in the erosion of their canyons about ten thousand feet of strata, giving a full series of formations from Lower Cretaceous to Quaternary.

The oldest rocks in this region, which are known to the writer, are a series of altered sedimentaries in the northeastern part of the basin. They are pretty certainly of pre-Cretaceous age and are underlain by quartz diorite[1] which is presumably intruded into them.

On Bridge Creek, near Mitchell, a great thickness of Cretaceous is exposed. The lower 2000 to 3000 feet of this section are typical Knoxville. The upper 1000 to 2000 feet are Chico.

Resting upon the Chico, near Mitchell, also showing typical exposures at Clarno's Ferry, is a presumably Eocene formation to which the name Clarno is given. This formation is made up entirely of tuffs,

[1] Determined by Frank C. Calkins.

ashes, and lavas. In places it contains many plant remains and is apparently in part a fresh water formation.

The John Day formation rests directly upon the Clarno at Clarno's Ferry. The basin in which it was deposited is quite different from that of the Clarno. It probably rests unconformably upon that formation. The Lower John Day beds are considerably contorted in some localities. Ordinarily they are colored a deep red. Fossil remains are exceedingly rare in this division.

The blue-green beds of the Middle John Day are very fossiliferous. They correspond to the Diceratherium beds of Wortman. The Upper or Buff beds of the John Day lap over the middle division and rest in places upon the older formations. The upper division corresponds to the Merycochœrus Beds of Wortman. As *Merycochœrus* does not occur in the John Day, the upper division will be called the Paracotylops Beds. This name is based on the new generic name proposed by W. D. Matthew for the Upper John Day oreodons, originally supposed to be *Merycochœrus*.

The Columbia lava, an extension of the lavas on the Columbia River to the north, rests unconformably upon the crumpled John Day formation. The name Columbia lava should be restricted to this horizon of the lavas in this region, as other beds included in this group belong in some cases to different geological periods.

The Cottonwood (Loup Fork) formation, near 1000 feet in thickness, rests upon the Columbia lava. The Van Horn Ranch plants, which have generally been considered as John Day, are from this horizon. Remains of a true John Day flora, which had not previously been known, were discovered by the University of California expedition in 1900. The discovery of the true stratigraphic position of the Van Horn Ranch flora explains the apparent inverted position of the Neocene formations in central Washington.

Resting on the worn edges of the Cottonwood Beds is the Rattlesnake formation, comprising several hundred feet of gravel, tuff, and lava.

In canyons cut through the Rattlesnake and Cottonwood are several terraces. Remains of elephants and later horses found in the lower terrace deposits show that they were formed in Quaternary time.

The paper was illustrated with lantern slides showing the principal formations and their relations to each other.

The Geology of the Great Basin in Eastern California and Southwestern Nevada. By H. W. TURNER, San Francisco, Cal.

The ridges of the western edge of the Great Basin in Nevada and eastern California are usually very complex in structure and composition. They comprise sediments of Paleozoic and Jura-Trias age much disturbed at some points by intrusions of granolites. In Tertiary time there were extensive lakes, and contemporaneous with these lakes and also later are lavas and tuffs in large amounts, chiefly rhyolites, andesites, and basalts.

The formation of the ranges, or at least their latest uplifts, date from the late Tertiary and post-Tertiary time.

They were elevated along normal faults, the valleys being in part subsided areas, often of the nature of rock basins, whose rims are composed of rocks older than the desert detritus.

There are some gneisses pretty certainly of pre-Cambrian age. These gneisses underlie Lower Cambrian sediments rich in fossil remains at some points. There is an extensive chert series containig abundant graptolites supposed to be of Lower Silurian age. There are Lower Trias beds in the Inyo Range and Jurassic limestone in the Pilot Mountains.

The Tertiary lake beds contain abundant plant, molluscan, and fish remains.

The paper was illustrated with lantern slides.

Notes on the Geology of the Three Sisters, Oregon. By H. W. FAIRBANKS, Berkeley, Cal.

The Three Sisters form a group of volcanic peaks upon the summit of the Cascade Range in central Oregon. They rise to a height of about ten thousand feet, and are quite similar in many respects to the other great volcanic peaks which mark the crest of the Cascade Range through Oregon and Washington.

This group of peaks is marked by the presence of a glacier nearly three miles long and half a mile wide.

To the north of the peaks recent volcanic activity is indicated by extensive flows of basic lavas. Volcanic eruptions have occurred since the glacial period, as shown by the relation of the lavas to the grooved and polished surfaces. A volcanic cone upon the North Sister lies in the path of the present glacier.

Illustrated by lantern slides.

A Sketch of the Pedological Geology of California. By E. W. HILGARD, Berkeley, Cal.

Owing to the great climatic diversity, the rainfall varying from two inches at the south to as much as eighty inches in the north, even a sketch of the soil conditions of California must take the climates into consideration. The cardinal difference between rock decomposition in arid as compared with humid climates lies in the retardation of kaolinization, as exemplified in the monoliths of Egypt and the granites of the Sierra Madre, as compared, *e. g.*, with the Alleghanies. Hence in northern California and on the higher Sierra Nevada we find loams and clay soils, while at the lower levels and in southern California the soils are "dusty" or sandy, except where derived from preëxisting clay formations, which give rise to "adobe," and in the upper valleys of the rivers of the Sierra, which carry the materials from the higher levels.

Throughout the middle and southern parts of the state, where no rains of consequence fall between May and November, not only is the soil mass usually of extraordinary depth, but is scarcely changed for several, sometimes for four to ten, feet. There is practically no subsoil in the usual sense, in the absence of clay; water, roots, and air penetrate together to depths impossible in the regions of summer rains, and hence the extraordinary endurance of drought, even by plants foreign to the arid region. Moreover, these soils almost universally contain high percentages of lime and potash, due to the absence of the leaching process, which, on the other hand, results in the formation of "alkali soils," too complex a subject to be dealt with here.

"*Sand*" in the arid soils is not merely quartz grains, but consists of all the original minerals, superficially decomposed. Hence sandy lands are here fully as rich as clay lands are elsewhere.

In the Great Valley it is easy to recognize by their microscopic characters the alluvial areas of the several rivers coming in from the Sierra. Even here the greater rainfall of the Sacramento is evidenced by loam and clay lands, as compared with the San Joaquin valley, where sandy and silty lands prevail altogether. As the rainfall decreases toward the Coast Ranges, the "lightest" are found under the arid lee on the west border of the valley. In its axis, in the "tule lands," as well as on the borders of the bays near its outlet, heavy clay soils are being formed in the slack water, while the streams coming from the Coast Ranges are bordered by light silty lands, the "truck lands" from

which San Francisco markets are supplied. Along the foothills of the Sierra there lies a belt of varying width of heavy red clay lands, probably derived from Ione formation, and frequently closely packed with gravel. These materials are intrinsically poor in plant food and being difficultly penetrable by roots, have caused much disappointment to settlers, and were the first to be treated by the energetic method of blasting with dynamite for fruit culture. They improve materially toward the south and in Fresno county form the basis for successful citrus culture. Higher up in the foothills come the characteristic red soils, the gold-bearing earths, mostly derived from the older slates and sedentary thereon. They are interpersed with patches of gray "granite" lands, which are very much less productive, being derived from the granodiorites, deficient in potash and phosphoric acid.

The soils of the Coast Ranges vary greatly, with their varying rock formations, among which are much clay and clay shale, forming correspondingly heavy soils. But the valleys also are filled with deep silty or sandy deposits. Southward the Coast Ranges are continued in the Sierra Madre, which forms the northern wall of the valley of southern California.

This valley, now subdivided into the drainage basins of the Santa Ana and San Gabriel, was undoubtedly originally a unit. This is proved by a terrace of "red lands," which extends all around from Redlands and Riverside to Los Angeles. Its subdivision was effected in late times by the great débris cone of the San Antonio Creek, which abutting against the Puente hills cut the drainage in two. The red soils are the special ones for citrus culture; but the sandy and silty alluvium of the two rivers also serves the same purpose.

The Neocene Basins of the Klamath Mountains. By F. M. ANDERSON, Berkeley, Cal. Presented by Andrew C. Lawson.

This paper is an attempt to show some of the more salient structural features of the Klamath Mountains, including not only their basins, but also their principal ranges. The three chief ranges of the group, extending in a northeasterly direction from the coast, and the drainage basins intervening and otherwise associated, form the main subject of discussion. Of the two systems of ranges crossing each other nearly at right angles, the northeast and southwest ranges are the older, and have exerted a controlling influence over the drainage

since their beginning. The principal rivers of the region — the Rogue River, the Klamath, and the Trinity — cut transversely across the more nearly north and south ranges, showing them to be younger in age than the lines of drainage followed by these streams, and accordingly younger in age than the east and west ranges.

The historical development of these drainage basins is shown by the deposits contained in them, and for some of them it antedates the later Cretaceous epochs at least. The earliest drainage of the basin of the Klamath lakes is shown to have been through the valley of Rogue River, and to have been diverted from that course to its present, by some of the later lava flows from the Cascades. Evidence is cited to show that during the Chico epoch this basin was not connected with that of the Pitt River or the Sacramento, and it is maintained that its individuality has been kept almost unchanged to the present. As one of the larger streams of the region therefore, the Klamath is younger in age than either the Trinity or Rogue River.

On the Age of Certain Granites in the Klamath Mountains. By OSCAR H. HERSHEY, Berkeley, Cal. Presented by A. C. LAWSON.

Small batholites and dikes of granite, quartz-mica-diorite and intermediate types are shown to occur at various places in the Klamath region, but in areas quite subordinate in extent to those of the metamorphic rocks into which they have been intruded. The same contains extensive areas of serpentine and instances are given of the granitic rocks having been intruded into the serpentine to prove that the granites are newer, in accordance with the determined relations of these rock types in the Sierra Nevada region, and the reverse of the supposed relation between the granite and the serpentine of the Coast Ranges.

The black slates of the Klamath region are divided into two distinct series, referred to as the Lower Slates and the Upper Slates. The former are considered Devono-Carboniferous in age, being in part equivalent to the Calaveras formation. The latter are correlated, on the evidence of their lithology and of their structural relations to the Lower Slates and to a certain extrusive greenstone formation similar to the diabase and porphyrite formation of the Sierra Nevada region, with the Mariposa formation of late Jurassic age. The intrusion of granite occurred later than the deposition of these Upper Slates. Also it is shown that

the granites are much older than the Chico formation resting on them as they had suffered much erosion prior to the Chico epoch.

It is finally concluded that the weight of evidence places the granitic intrusion just about at the close of the Jurassic period. The effect of the argument is to show that there is a sound basis for the inference heretofore entertained that the Klamath Mountains belong rather to the Sierra Nevada system than to the Coast Ranges and may be considered a sort of outlier to the former.

The Drainage Features of California. By ANDREW C. LAWSON, Berkeley, Cal.

A comparative study of the geomorphy of the Sierra Nevada and the Coast Ranges. There is a remarkable contrast in the character of the river valleys in the two mountain systems, those of the Sierra Nevada being consequent and the geomorphy immature, while those of the Coast Ranges are subsequent and the geomorphy mature. In the Coast Ranges the geomorphic profiles of the river valleys, leaving out of consideration the head-water streams, are not so steep as in the Sierra Nevada, and the valleys are much wider as a general rule. The divides are rounded or ridge like, with but small remnants of the earlier geomorphic cycle identifiable, in the Coast Ranges, while in a large part of the Sierra Nevada the divides have a marked table or plateau form. The drainage of the Coast Ranges is clearly controlled by the structure of the country while the streams of the Sierra Nevada cut *across* the strike of the rocks, and have made but little headway in the working out of canyons *along* the strike of the softer formations.

The Klamath River is regarded by the author as partly having the consequent character of the Sierra Nevada drainage and partly the character of the Coast Range drainage. The Trinity River and its prolongation in the lower Klamath belongs to the Coast Range system being parallel to the strike of the country and in part mature in its development, while the upper Klamath is consequent and young. This affords us a basis for the separation of the Klamath Mountains from the Coast Ranges, and supports the orogenic correlation of the Klamath Mountains with the Sierra Nevada. The comparison thus made points clearly to the conclusion that the Sierra Nevada and probably also the Klamath Mountains are of later date than the emergence of the Coast Ranges which inaugurated the present cycle of geomorphic evolution. But the subsequent valleys of the Coast Ranges are in

several instances known to have been evolved after the deformation of the Pliocene, and we are thus forced to place a very late geological date upon the tilting of the Sierra Nevada orographic block.

A Feldspar-Corundum Rock from Plumas County, California. By ANDREW C. CLAWSON, Berkeley, Cal.

Mr. Turner, of the United States geological survey, has called attention to the prevalence of feldspathic "albitic" dykes cutting serpentine in various parts of the Sierra Nevada. The rock of which the present paper treats apparently belongs to this series of dykes. It occurs as a white coarse-grained dyke cutting the serpentine of the eastern flank of Spanish Peak, Plumas county. The rock is composed of 84 per cent. of oligoclase and 16 per cent. of corundum in crystals up to over two inches in length, and rather irregularly distributed through the feldspathic groundmass.

The following is an analysis of the feldspar:

SiO_2, 61.36; Al_2O_3, 22.97; Na_2O, 8.08; CaO, 5.38; H_2O, 1.72. Total, 99.51; Sp. g, 2.63.

The occurrence is of special interest as one of the rare cases of a rock supersaturated with alumina, and its occurrence as a dyke in a rock devoid of alumina, soda, and lime is of especial interest as supporting a case of extreme differentiation of rock magma.

The foregoing synopses were prepared by the authors of the papers.

JOHN C. MERRIAM.

Reviews

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.

WINCHELL[1] discusses the general structural geology of northeastern Minnesota. The ancient rocks of this area he places in two main systems, the Archean and the Taconic. The former is further subdivided into the Upper and Lower Keewatin, separated from each other by an unconformity. The Pewabic quartzite also is placed with the Keewatin, but is not assigned to either of the main divisions. Overlying the Archean with strong unconformity is the Taconic, represented by Animikie and Keweenawan rocks, these divisions being supposed to represent respectively the Lower and Middle Cambrian of other parts of the country. The Coutchiching and Laurentian rocks before mapped as separate formations are now included within the Keewatin.

The Lower Keewatin comprises greenstone, with associated surface volcanics which are both subaërial and subaqueous, argyllitic slates, siliceous schists, quartzites, arkoses, "greenwackes," iron ores, and marble.

[1] The Geology of Minnesota, by N. H. WINCHELL, U. S. GRANT, JAMES E. TODD, WARREN UPHAM, and H. V. WINCHELL: Final Rept. of the Geol. and Nat. Hist. Surv. of Minnesota, Vol. IV, 1899, pp. 630. With thirty-one geological plates.

Structural geology of Minnesota, by N. H. WINCHELL: Final Rept. Geol. and Nat. Hist. Surv. of Minnesota, Vol. V, 1900, pp. 1–80, 972–1000.

The first of these volumes contains an account of detailed field work in northeastern Minnesota, with incidental discussion of general problems. The area is treated by counties and smaller arbitrary geographical divisions, in the description of which several men have taken part. This manner of treatment leads to repetition in the discussion of the general geological features, and in many cases it is extremely difficult to correlate the facts recorded in the different sections.

Volume V contains an account of the general structural geology of the state by Professor Winchell based on the detailed work described in Vol. IV. This general discussion of Vol. V is reviewed, with such reference to the facts recorded in Vol. IV as is necessary to make the summary intelligible.

Dr. Grant's views, as indicated in the detailed descriptions of special areas, in some cases differ somewhat widely from those of Professor Winchell.

The greenstone, designated the Kawishiwin, is the oldest known rock in the state, and is supposed to represent a portion of the original crust of the earth. With its associated volcanic rocks it occurs in two main belts. The southern belt begins in the vicinity of Gunflint Lake and extends westward by way of Gobbemichigamma Lake, the Kawishiwi River, and White Iron Lake, to Tower, and indefinitely westward. The northern belt of greenstone enters the state from Hunters' Island, appearing conspicuously at the south side of Basswood Lake. At Pipestone Rapids and Fall Lake it widens southward and apparently unites at the surface with the southern belt, the overlying Upper Keewatin being absent for a distance of a few miles. But further west it is again divided by the Stuntz conglomerate, the northern arm running to the north of Vermilion Lake, west of which its extension is unknown, and the southern one running south of the lake.

The fragmental stratified rocks of the Lower Keewatin are most important toward the western part of the area of exposure of crystalline rocks. They occupy a wide area, south, west, and north of Tower. The iron ores of Tower and Ely on the Vermilion iron range occur in the upper part of the Lower Keewatin. It is probable that the immediately enclosing rock is a sedimentary one, although composed of the elements of a basic eruptive. The sediments extend south to the Giants Range of granite, where they are metamorphosed to mica-schists by the granite. Toward the west they extend as far as the Mississippi River and its northern tributaries and across the Bowstring, although the drift prevents the delimitation of the belt. To the northwest they extend toward Rainy Lake, in this direction being converted into mica-schists and gneisses by the intrusion of granite; in unmodified form they are found at one point only on Rainy Lake. These fragmental rocks of the Lower Keewatin doubtless also underlie most of the central and southwestern part of the state as far as the Minnesota River. Here they dip beneath the later formations in the southwestern portion of the state, and probably occupy a wide patch in South Dakota. South of the Giants Range they occur also, but as they are covered by the gabbro and Animikie toward the east and the drift deposits of the St. Louis valley toward the west their geographic boundaries are mostly unknown. They appear in the central and western portions of Carlton county, where their line of separation from the Upper Keewatin is quite obscure, and in the central and western portions of Morrison county. The Lower Keewatin

marble is seen at Lake Ogishke-Muncie and at Pike Rapids on the Mississippi.

The Lower Keewatin was terminated by a period of extensive folding and intrusions of granite and basic rocks.

The Pewabic quartzite belongs with the Keewatin, but whether to the Lower or Upper Keewatin is not known. This formation includes altered quartzites and iron-ores between the granite and gabbro in the immediate vicinity of Birch Lake and small patches of similar rocks in Sec. 30–62–10; on the south shore of Disappointment Lake; on the north shore of Fraser Lake; on the south shore of Gabbemichigamma; at Akley Lake, forming the so-called Akley Lake series extending from the west side of Sec. 34–65–5 to the eastern part of Sec. 27–65–4.

The Upper Keewatin occurs in troughs in the Lower Keewatin, and particularly in one main trough the axis of which is traceable from Vermilion Lake to Saganaga Lake. The northern arm of this syncline, consisting of granites, gneisses, associated mica-schists, and in some places earlier greenstones, extends from the northern part of Vermilion Lake through Basswood Lake to the northern side of Hunter's Island. The southern arm, consisting of Lower Keewatin green-schists and other schists, penetrated by the granite of the Giants Range, extends from Pokegama Falls on the southwest toward the northeast, until cut out by the encroachment of the gabbro from the south. The Upper Keewatin consists very largely of conglomerates, but also includes graywackes, argyllites, quartzites, and jaspilites, in general coarser than those of the Lower Keewatin. Volcanic rocks are less important than in the Lower Keewatin, although still present. There is no general order of succession in the Upper Keewatin excepting that it can be said that it is in general conglomeratic at the bottom.

After Upper Keewatin time both the Lower and Upper Keewatin were subjected to another folding, the axis of which had a general parallelism with the earlier folding, with the result that the Upper Keewatin lies in narrow synclines in the Lower Keewatin and in places is nearly or quite vertical.

Associated with the Keewatin rocks are granites of at least two periods of intrusion, one later than the Lower Keewatin and one later than the Upper Keewatin. The later granite is believed to be represented by the higher parts of the Giants Range and the Snowbank Lake granite. The earlier granite is represented by the granites at Kekequabic Lake, Saganaga Lake, Basswood Lake, Burntside Lake,

Vermilion Lake, Lac la Croix, and Kabetogoma Lake. The origin of the granite is discussed and the same conclusions reached as in a previous article.[1]

The Taconic.— This is unconformably above the Keewatin rocks. It comprises the Animikie and Keweenawan divisions.

The Animikie rocks enter the state at Pigeon Point, run westward along the international boundary to the eastern part of Secs. 22 and 27 T. 65 N., R. 4 W. They reappear again southwestward from Birch Lake on the northwest side of the gabbro mass, and thence continue along the south side of the Giants Range, constituting the Mesabi iron series, to Pokegama Falls. The higher parts of the Animikie are best developed toward the east, while the lower parts are best developed toward the west.

The Animikie rocks comprise the Pokegama quartzite, Mesabi iron-bearing formation, some limestone and slate, all strictly conformable with one another. The thickness is several hundred feet, sometimes reaching nearly 1000 feet. The dip of the series is uniformly to the south, 8° to 12°.

The iron-bearing formation and the Pokegama quartzite constitute the base of the formation. The quartzite in places is beneath the iron formation; in other places it is in the same horizon; and in still others is above the iron formation. Commonly the base of the Animikie is marked by a conglomerate, containing débris from the underlying Keewatin rocks. This is a narrow horizon which soon graduates upward into a quartzite, known as the Pokegama quartzite, from its typical development near Pokegama Falls on the Mississippi River. The thickness of the quartzite is not known to exceed fifty feet, and is sometimes less than twenty-five feet.

Above the quartzite, or in alternating beds with it, or below it, appears the iron-bearing or taconyte member of the Animikie, which contains the iron ore deposits of the Mesabi iron range. The ore is usually hematite in the western part of the range and magnetite in the eastern part. It was previously supposed to have been derived from the alteration of a greenish glauconitic sand-rock; but later work has seemed to show that the green-sand is a volcanic sand, and that the so-called taconitic rock itself has resulted from igneous forces. This

[1] The origin of the Archean Igneous Rocks, by N. H. WINCHELL: Proc. Am. Assoc. Adv. Sci., Vol. XLVII, 1898, pp. 303, 304 (Abstract). Also Am. Geol., Vol. XXII, 1898, pp. 299-310. Summarized JOUR. GEOL., Vol. VII, 1899, p. 194.

is accounted for by supposing a chain of active volcanoes to have existed where the Mesabi iron range is now found. These volcanoes yielded flows and ejectamenta to the adjacent waters which have been modified into the various phases of the iron formation now seen. This volcanic epoch may have a deep-seated connection with the Cabotian or lower division of the Keweenawan (described later).

Above the iron-bearing member is an impure dark colored limestone a few feet in thickness, not exceeding twenty. It extends apparently the whole length of the Mesabi range, but has been identified in two places only, Sec. 7, T. 58 N., R. 17 W., and doubtfully on the shores of Gunflint Lake. This limestone may be regarded as the basal horizon of the next overlying rock.

The black slate is probably several thousand feet in thickness and constitutes the bulk of the Animikie. In the neighborhood of Gunflint Lake it has been divided by Dr. Grant into a lower black slate division and an upper graywacke-slate division, both of which members are interleaved with diabase sills.

In the Indian reservation at Grand Portage and at various places along the Grand Portage trail is a graywacke, which is supposed to overlie the black slate member, but its extent and stratigraphical position have not been satisfactorily established.

The top of the Animikie has not been identified. The first recognizable datum plane after the close of the Animikie is the Puckwunge conglomerate, supposed to be the fragmental base of the Keeweenawan.

At one or two places southwestward from Birch Lake, and at Little Falls on the Mississippi River, and in Morrison county, the Animikie has been converted into a mica-schist.

The age of the Animikie is believed to be Lower Cambrian for the following reasons: It graduates upward into Upper Cambrian rocks as seen on the south side of Lake Superior. The derivation of the iron ores from a glauconitic green-sand indicates that large quantities of foraminiferal organisms once lived in the Animikie ocean, and Matthew has shown the existence of foraminiferal organisms associated with the iron ore in the St. Johns group of New Brunswick. Further the Animikie has a uniformly low dip, while the lower strata are all highly tilted. There must therefore have been a great lapse of time between the deposition of the two series.

The Keweenawan.—The Puckwunge conglomerate is taken to be

the *fragmental* base of the Keweenawan, although certain igneous rocks which antedate it and which perhaps are contemporaneous with the upper portions of the Animikie are also called Keweenawan. The conglomerate is found at Grand Portage Island, at Isle Royale, on the Baptism River, at Little Marais, on Manitou River, at the deep well at Short Line Park near Duluth, and at New Ulm.

Above this conglomerate are conglomerates and sandstones of Keweenawan age which are stratified with lavas of diabasic nature. Still higher up the eruptive rocks become less in quantity and the fragmental rock is a sandstone, known as the Hinckley sandstone, quarried in the gorge of the Kettle River in Pine county. This in turn grades up into typical Upper Cambrian sandstones of the St. Croix valley. The term Potsdam is restricted to the Puckwunge conglomerate and the hardened quartzites immediately overlying it, represented by the Sioux quartzite, the Baraboo and Barron county quartzites of Wisconsin, the quartzite at Grand Portage Island, and west of Grand Portage village, the New Ulm quartzite in Cottonwood county, and the quartzite in Pipestone county.

The igneous rocks of the Keweenawan vary in age from the late Animikie time to the top of the Keweenawan series. They are divided into two groups, the Cabotian or Lower Keweenawan, and the Manitou or Upper Keweenawan.

The Cabotian division includes gabbro and contemporaneous red rock and their surface lavas, and all other dikes and sills which are associated with, but younger than, the Animikie clastic rocks, and which are older than the Puckwunge conglomerate. The lower member of the Cabotian is the gabbro, which covers an enormous area. It extends on the east to East Greenwood Lake in T. 64, N., R. 2 E. On the north it is bounded by the Animikie strata of the Mesabi iron range. Its westernmost exposure is in the vicinity of Short Line Park, Duluth. The southern limit is irregular, swinging from East Greenwood Lake in a zigzag manner through T. 63 N., R. 1 W., T. 62 N., R. 2 W., T. 62 N., R. 4 W., T. 60 N., R. 6 W., T. 60 N., R. 7 W., T. 58 N., R. 10 W., and T. 55 N., R. 11 W., to Duluth.

Along the northern and northwestern side of the great gabbro mass, the gabbro is plainly intrusive on the older formations, Animikie and Keewatin.

From the northern border of the gabbro many sills offshoot and penetrate the Animikie strata parallel to the bedding. These are known as the Logan sills.

Near its contact with the underlying rocks, both the Animikie and Keewatin series, there are various altered rocks which can be connected in places with the gabbro and in places with the underlying rocks. To these altered rocks the term muscovadyte has been applied. It includes the various so-called peripheral phases of the gabbro.

On the southern and eastern border the gabbro is penetrated by and penetrates in a confused manner the red rock, with which it alternates both structurally and areally. It is believed to have resulted from the metamorphism by the gabbro of the Animikie, and perhaps earlier fragmentals.

As the granites of the Archean are believed to have resulted from the softening of acid fragmentals, so the gabbro may probably have been the result of the metamorphism or re-fusion of the Keewatin greenstones.

The anorthosite masses of the Beaver Bay diabase, supposed by Lawson to be of Archean age and to underlie unconformably the Beaver Bay diabase, are believed to represent segregation phases in the main gabbro flow, and to be the same as anorthosite masses in the gabbro proper to the west.

The Beaver Bay diabase is believed to represent the upper portion of the great gabbro flow, and to be due to the first and greatest movement of the gabbro toward Lake Superior. The Logan sills belong to this part of the gabbro flow.

The Manitou division of the Keweenawan includes the surface flows, sills, and dikes which accompanied and followed the Puckwunge conglomerate. These eruptives, with the clastics associated with them, do not have a thickness in Minnesota of more than 1000 feet. These lava sheets extend along the shore of Lake Superior from near Baptism River to near Grand Marais, except where replaced at intervals by the Beaver Bay diabase or some of the intersheeted fragmentals. They occur also in the neighborhood of Grand Portage Bay, but their extent here is not definitely known.

General.—The most important petrological conclusions determined from the examination of the Minnesota crystalline rocks, are three in number:

1. All the granites of the Archean can be explained on the assumption that they are intrusives representing the metamorphosed conditions of clastic rocks adjacent to the observed intrusions, rendered plastic by the force of dynamic metamorphism accompanied by moisture.

2. The basic Keweenawan gabbro and its derivatives are derived from the metamorphism and complete re-fusion of the Archean greenstones and their attendants.

3. The green-sand of the Mesabi iron-bearing formation appears to have resulted from a volcanic sand and the taconite itself from igneous forces.

Comment.—The three main petrological conclusions announced by Professor Winchell as the most important results of his final petrological work, summarized in the closing general paragraph, would be dissented from by most of the other geologists who have worked in this area.[1]

The Cambrian age of the Animikie strata has long been maintained by Professor Winchell, and above are summarized his arguments in support of this position. The first argument, that the Animikie grades into the Upper Cambrian rocks, is not in accord with the observations of most of the geologists above referred to. The second argument, based on the similarity of the unaltered green-sand in the Mesabi district with that in the Cambrian of the eastern United States, loses weight when we consider the fact that the similarity is not great, the differences being many and significant; and if the similarity were complete, the correlation would involve laying too much stress on lithological similarity of widely separated formations. Professor Winchell's latest conclusion, that the Mesabi green-sand is volcanic and not organic, while entirely dissented from by others who have studied this rock, in itself spoils his argument based on similarity. The third argument in favor of the Cambrian age of the Animikie, based on the extent of the unconformity beneath the Animikie, has little value when unsupported by the other lines of evidence. Professor Winchell's conclusion as to the Cambrian age of the Animikie strata is thus not adequately sustained by the reasons given. The view that the Animikie is Upper Huronian (pre-Cambrian) is the commonly accepted one. The evidence favoring this view is summarized by Van Hise.[2]

Further comment on the above work would require reference to the detailed observations made in northeastern Minnesota during the

[1] Some of these geologists are: R. D. Irving, C. R. Van Hise, J. Morgan Clements, W. S. Bayley, U. S. Grant, J. E. Spurr, A. H. Elftman, C. K. Leith.

[2] Correlation Bulletin, Archean and Algonkian, No. 86, U. S. Geol. Survey; Principles of Pre-Cambrian Geology, Sixteenth Annual Report, U. S. Geological Survey.

past four years by the Lake Superior Division of the United States Geological Survey.[1] The results of this work have not been published and any reference to the conclusions reached would be premature. In general it may be stated that now, as in the past, there is divergence in the conclusions reached by the Minnesota Survey and by the United States Geological Survey concerning the position and importance of the unconformities, correlation of series, and nomenclature.

C. K. LEITH.

The Norwegian Polar Expedition, 1893 to 1896. Scientific Results. Edited by FRIDTJOF NANSEN. Vol. I. Longmans, Green, & Co.

The object of the report of which this is the first volume is stated in the preface to be "to give in a series of separate memoirs a complete account of the scientific results of the Norwegian North Polar Expedition of 1893 to 1896." The first volume contains the following papers: "The Fram," 16 pp. with three plates; "The Jurassic Fauna of Cape Flora, Franz Josef Land," by J. F. Pompeckj, with a "Geological Sketch of Cape Flora and its Neighborhood," by Fridtjof Nansen, 147 pp. with three plates; "Fossil Plants from Franz Josef Land," by A. G. Nathorst, 26 pp. with two plates; "An Account of the Birds," by Collett and Nansen, 53 pp. with two plates; "Crustacea," by G. O. Sars, 137 pp. with thirty-six plates.

The fossil fauna brought back from Cape Flora was collected by Nansen during the period of his stay with Jackson at Elmwood, Cape Flora, Franz Josef Land. The collection was studied by J. F. Pompeckj, whose descriptions of the fossils constitute the second part of the volume. Collections from the same localities secured by the Jackson-Harmsworth expedition were examined and described by Mr. E. T. Newton, but the conclusions reached by Pompeckj and by Newton as to the age of the strata are somewhat at variance.

The condition of preservation of the fossils is poor, and many species, particularly of lamellibranchs, could not be identified even generically. The collection shows that a fauna of at least twenty-six different species occurs in the Jurassic sediments about Cape Flora.

[1] The reports on this area in preparation by the survey are: Lake Superior Iron Ores, to appear in the Twenty-first Annual Report; Monograph on the Vermilion Iron Bearing District of Minnesota, and Monograph on the Mesabi Iron District of Minnesota.

The collections of the Jackson-Harmsworth expedition from the same region only afforded fourteen species, and seventeen of the species studied by Pompeckj were not recorded by Newton. The fossils were found at five localities, and at three of these they were *in situ*. From the results of his study of the Jackson-Harmsworth collections, Newton concluded that the "Lower Oxfordian rocks," and probably the equivalent of the "British Kellaway rocks," are represented in the Jurassic strata underlying the basalt at Cape Flora. Pompeckj, however, was able to identify four horizons in a much more definite manner. The lowest of these is Bajocian, and probably the lower Bajocian; the second is Lower Callovian, the zone of *Macrocephalites macrocephalus;* the third is the Middle Callovian, the zone of *Cadoceras milaschewici;* and the fourth is Upper Callovian, the zone of *Quenstedtoceras lamberti*. The Bajocian fauna is apparently without analogy in the arctic region, but seems to show direct affinities with the central European Jura. The Callovian faunas are very near those of the Russian Callovian, and these two regions were probably in direct communication during that part of Jurassic time. It is worthy of note that there is hardly any likeness between the fauna of Cape Flora and that of Cape Stuart, East Greenland.

In the fossils, one rather striking feature is the paucity of gastropods, one species only having been found in the marine fauna, while cephalopods and lamellibranchs are relatively much more abundant. This general relation also holds for the arctic fauna of northern Europe.

The identification of these beds at Cape Flora gives the northernmost locality of Jurassic beds, since the latitude of Cape Flora is nearly 10° farther north than that of the next most northerly deposit of this age. These beds show that the Bajocian sea of north Europe extended far to the northward. Spitzbergen was probably not covered; neither was Novaja Semlja, and these two islands were probably connected with each other and with Europe. This land area may have been extended northward to Franz Josef Land. The sea seems to have lain north and west of this land. The Petchora Basin sea is conjectured to have extended north between Spitzbergen and Novaja Semlja, and to have been bounded on the north by land in the region of Franz Josef Land. Spitzbergen is conjectured to have been connected with the Franz Josef Land of the Callovian epoch. The Callovian sea is conjectured to have extended east to Alaska. Toward the

end of the Callovian epoch the sea receded to the southward from Franz Josef Land, while Spitzbergen and Novaja Semlja were partly submerged.

The main body of the sedimentary Jura of Cape Flora extends from sea level up to 575 feet. It is fossiliferous in horizons only. The Callovian part of the Jura extends from 370 feet to 575.

The fossil plants secured by Nansen, also from the region about Cape Flora, were placed in the hands of A. G. Nathorst, and his report upon them constitutes Part III of the volume. These plant remains are all fragmentary and very poorly preserved, so that in most instances no specific identification could be made. Out of the twenty-nine forms recognized, only two are specifically identified with certainty, though seven others are compared with described species. The conclusions reached by Nathorst as to the age of the plant-bearing deposit is that "it was formed toward the close of the Jurassic or commencement of the Cretaceous period, without our being able at present to settle which." The fossil plants occur in two beds which lie between certain of the seven extrusive basaltic flows.

The account of the birds is divided into four sections, the first treating of the journey along the north coast of Siberia; the second gives the observations made while the "Fram" was drifting with the ice before Nansen left it; the third gives the observations made during the sledge journey of Nansen and Johansen; while the fourth gives the observations made on the "Fram" after Nansen left it in March 1895. This section of the report is a technical description of the species of birds seen.

The section on the Crustacea is in much detail and will be of great interest and value to zoölogists. The conclusion is reached that the bulk of the pelagic animals found in the North Polar basin were derived from the west through the Atlantic current flowing in beneath the superficial Siberian current. It has also been found that forms which have hitherto been regarded as quite southern in distribution are found in the polar sea.

The volume also makes some announcement of the contents of future volumes of the report. The second volume is announced to contain "The Astronomical Observations and their Results," "Terrestrial Magnetism," and "Pendulum Observations and their Results." The third volume will deal with "The Oceanography of the North Polar Basin," "Hydrometers and their Errors, especially those caused

by the Variation of the Surface Tension of Liquids," "The Depths and Submarine Features of the North Polar Basin, with chemical Analyses and Microscopical Composition of the Deep Sea Deposits," "Diatomaceæ and Algæ living on the Drifting Ice and in the Sea of the North Polar Basin." Many other memoirs are announced for still later volumes. It is stated that the number of volumes will probably be five or six, which it is hoped may be finished in the course of about two years. These volumes will not only furnish a large body of information about a little-known region, but some of them will deal with questions of world-wide application. The reports are to be issued in the English language only.

R. D. S.

The Pleistocene Geology of the South Central Sierra Nevada, with especial reference to the Origin of the Yosemite Valley. By HENRY WARD TURNER. Proceedings of the California Academy of Sciences. Third Series, Vol. I, No. 9; 9 Plates; pp. 361–321.

This paper gives a brief outline of the pre-Pleistocene orogenic history of the Sierra Nevada, the orogenic movements of the Pleistocene, and a brief sketch of the Pleistocene history of the region, as an introduction to the discussion of the origin of the Yosemite Valley. The Sierran period, the period of high lands preceding glaciation, is included in the Pleistocene. Some brief notes on the glacial period are also given, and the conclusion reached that there were two periods of glaciation separated by an interval of deglaciation, though the evidence on this point is not looked upon as altogether conclusive. The assumption that in the interior of the continent there were two (and not more) well-marked glacial epochs, needs to be modified in the light of the investigations of the last few years. The brief statement concerning the cause of the glacial period, also seems not to take account of the latest and most satisfactory views on this subject.

The several hypotheses which have been advanced concerning the origin of the Yosemite are considered, and the conclusion reached that this valley was not scooped out by the ice (Muir); that it is not a river-cut canyon, the walls of which were made vertical by the sapping action of ice (Johnson); and that there is no adequate evidence that it is due to a drop fault (Whitney, *et. al.*); but that it owes its origin to river

erosion influenced, in its topographic results, by the strong jointing of the rock of the region. This view, however, does not preclude the glaciation of the valley, but ascribes to the ice a very insignificant part in its excavation. R. D. S.

A Record of the Geology of Texas for the Decade ending December 31, 1896. By FREDERIC W. SIMONDS, PH.D. Reprint from Vol. III of the *Transactions of the Texas Academy of Science.* [Austin?], August, 1900, pp. 280.

In 1887 the U. S. Geological Survey published Bulletin No. 45, by Professor R. T. Hill, upon "The Present Condition of Knowledge of the Geology of Texas." Although that bulletin was not a bibliography in the ordinary meaning of the word, it mentioned the chief publications upon the geology of the State of Texas up to 1886, and gave the general results of the work of the authors. The present volume by Dr. Simonds is an annotated bibliography covering the succeeding ten years. That particular decade has been the most fruitful period in the history of geological investigation in the State of Texas, and, as a consequence, Dr. Simonds' list is the most important one that could have been made of any limited period.

No one who has attempted a piece of bibliography will fail to appreciate this valuable contribution to geologic literature. Such publications represent a great deal of dead-work, much of it of a dreary kind. But Professor Simonds has rendered a genuine service both to the people of Texas and to the science of geology by bringing these titles together and giving a résumé of the contents of each paper. As a rule but few persons know just what has been published upon the geology of a given state, or where to lay hands upon it. This list fills the want, so far as Texas is concerned during the period 1886–1896.

The titles are arranged according to the alphabetic order of the authors, and there is an index of both authors and subjects at the end of the volume.

J. C. BRANNER.

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